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[1] A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

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68. Fred J. Foster	1938-1939	Asheville, N. C.
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71. John Van Oosten	1941-1942	St. Louis, Mo.
72. John Van Oosten	1942-1943	(No meeting.)[2]
73. John Van Oosten	1943-1944	(No meeting.)[3]
74. John Van Oosten	1944-1945	(No meeting.)[3]
75. John Van Oosten	1945-1946	(No meeting.)[3]
76. Joe Hogan	1946-1947	St. Paul, Minn.
77. H. H. MacKay	1947-1948	Denver, Colo.

[2] The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.
[3] No annual meeting scheduled because of the war.

In Memoriam

Hildebrand, Samuel F., Washington, D.C.

Kaul, William, St. Mary's, Pennsylvania

Johnston, William D., Park House,
Montrose, Scotland

Predmore, Henry E., Ann Arbor, Mich.

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Part 1
Papers

SOME TRENDS IN THE COMMERCIAL FISHERIES OF LAKE OF THE WOODS, MINNESOTA

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ABSTRACT

Since 1884, when commercial fishing first started on Lake of the Woods, the commercial catch and the fish populations have changed markedly. Lake sturgeon (*Acipenser fulvescens*) which was originally the most important commercial fish is now almost extinct. The lake whitefish (*Coregonus clupeaformis*) has also shown a striking decline. Intensive commercial fishing was an important factor in the decline of these species. The practical disappearance of other species which were not subject to heavy fishing, the longnose sucker (*Catostomus catostomus*), goldeye (*Amphiodon alosoides*), and quillback (*Carpiodes cyprinus*), however, suggest some basic change in habitat. Destruction of the spawning beds in the Rainy River by pulp-mill wastes was probably the most important of these habitat changes. A correlation was found between the strength of year classes of saugers (*Stizostedion canadense*) and June rainfall. Recent declines in the population of yellow pikeperch (*Stizostedion vitreum*) do not appear to be caused by pollution since its effects on the habitat were evident long before declines appeared in the pikeperch catch. Saugers and yellow perch (*Perca flavescens*) seem to be on the increase. These species compete with the pikeperch for food. During the summer months, the saugers usually occupy deeper waters than the pikeperch but not consistently enough to preclude competition. The present fishing methods are selective and favor the survival of saugers and yellow perch which are not being taken in proportion to their abundance nor being exploited as intensively as the pikeperch. It is recommended that fishing methods be adjusted to permit greater utilization of yellow perch and saugers.

INTRODUCTION

Commercial fishing was started on Lake of the Woods about 1884. Comparable statistics are not available to follow accurately all of the changes which have occurred in the fishing intensity and in the fish catch over the ensuing 60-year period, but many of the changes were sufficiently great to be detected even with the incomplete data. The fish population is now quite different from what it was when the fisheries were investigated by Evermann and Latimer (1910). It is not possible to determine exactly the factors responsible for these changes, but certain relationships are evident which indicate that overfishing, selective fishing, and environmental changes associated with pulp-mill pollution have had significant effects on the fish population.

Lake of the Woods is an irregularly shaped body of water 1,485 square

[1] Formerly of Minnesota Department of Conservation, St. Paul, Minnesota.

miles in area (Meyer and White, 1917). The southern portion, known as the Big Traverse, is an expanse of relatively shallow water, about 25 miles across and 35 feet deep. It has low shores with sand beaches and floating muskeg. The northern portion, or Little Traverse, consists of numerous bays and inlets, bounded by rock shores and dotted with thousands of rocky islands. It is much deeper and in some places supports lake trout (*Cristivomer namaycush*) and whitefish. Approximately one-third of the lake including most of the Big Traverse is in Minnesota and most of the Little Traverse is in Ontario and Manitoba, Canada.

The principal tributary stream is the Rainy River which provides about two-thirds of the water entering the lake. The outlet is to the north, and drains into Hudson Bay through the Winnipeg River. Outlet dams permitted a range in average monthly water stages at Warroad of 5.8 feet during the period 1937 to 1940.[2] There is no major thermal stratification in the Big Traverse, and oxygen is abundant at all depths. The water is moderately soft with a total alkalinity of 45 to 68 p.p.m. of calcium carbonate. Secchi-disc readings vary between 0.5 and 1.5 meters, depending upon the amount of plankton and silt suspended in the water. During August, there is usually a heavy bloom of blue-green algae, principally *Aphanizomenon flos-aquae* (L.) Ralfs. The average volume of the wet bottom fauna per square-foot sample was 2.0 cubic centimeters as determined by the water-displacement method on 114 samples. Midge larvae (Tendipedidae) and mayfly nymphs (Ephemeroptera, principally *Hexagenia mingo*) are the most important bottom organisms.

In the present study, most of the data refer only to the Minnesota side of the lake and to the fisheries in the Big Traverse. In general, similar changes have occurred in the Canadian fisheries. Evermann and Latimer (1910) recorded results of their investigation of the Lake of the Woods fisheries in 1908 and 1909 and collected statistics on the fish catch from 1888 to 1909. The United States Bureau of Fisheries published data on the total catch in Lake of the Woods from 1913 to 1939 in the series, "Fishery Industries of The United States." Production statistics for the Minnesota portion of the lake for the years 1933–1945 have been published in the annual and biennial reports of the Minnesota Department of Conservation. In addition, the annual reports of individual fishermen to the Minnesota Department of Conservation from 1932 to 1946 were examined to secure data on the annual catch per unit net.

In 1939 the Minnesota Department of Conservation, in cooperation with the University of Minnesota, initiated a field investigation of the commercial fisheries on Lake of the Woods. The entire summers of 1939, 1940, and 1941 were spent at the lake and field trips were made during the winters of 1940–1941 and 1941–1942, and in the summers of 1942–1943. Additional field data have been collected by other members of the Minnesota Fishery Research Unit in 1944, 1945, and 1946. The field studies included limnological observations, minnow seining, experimental

[2] Records of the International Joint Commission on Water Levels of Lake of the Woods.

gill netting, and measuring and weighing fishes taken in commercial nets. Large numbers of scales were taken for life history studies.

The Fishery

Commercial fishing in the Minnesota waters of Lake of the Woods began in 1884, when William Zippel settled on the south shore of the lake near the mouth of the Rainy River. Evermann and Latimer (1910) state that 4 pound nets were in use in 1888. By 1895, the commercial fisheries were extensively developed in both Minnesota and Canadian portions of the lake. The amount and type of gear which have been used since that time have varied considerably (Table 1), but three principal types of nets have been employed. The first nets were pound nets, fished near shore with leads up to 80 rods long. Except for a few years, the number of pound nets fished in the Minnesota waters has been between 60 and 80. Fyke nets are used primarily in the smaller bays for brown

Table 1.—*Average number of pound nets, fyke nets, and gill nets licensed in Minnesota waters of Lake of the Woods, 1888–1946*

The data from 1888 to 1910 were taken from Evermann and Latimer (1910). The other data came from Minnesota Department of Conservation records]

Years	Pound nets	Small pound[1] nets	Fyke nets	Gill nets (1,000 feet)
1888–1889	7	0	0	0
1890–1894	65	0	0	0
1895–1899	129	0	0	0
1900–1904	71	0	0	0
1905–1909	61	0	0	0
1910–1914	[2]88	0	[2]24	0
1915–1919	[2]100	0	[2]30	[2]75
1920–1924	[2]84	0	[2]30	[2]75
1925–1929	[2]60	0	[2]100	[2]90
1930–1934	60	8	87	89
1935–1939	60	25	64	87
1940–1944	50	21	57	87
1945–1946	36	20	19	88

[1] These nets have 600-foot leads, and pots not in excess of 22 feet deep
[2] The number licensed was not over this number, but may have been somewhat less

bullhead (*Ameiurus nebulosus*), yellow perch, and pike (*Esox lucius*). Although up to a hundred fyke nets were used from 1925 to 1935, the number has declined sharply in recent years. Legal gill nets in the Minnesota waters have 4-inch, stretched measure, mesh and their number has remained fairly constant since 1915 when they were first licensed.

The fishing intensity has been modified not only by changes in the gear but also by various legal restrictions on the catch. Minimum size limits were first established in 1905 and then modified from time to time. The length of the fishing season has also undergone change. In 1895 the law permitted fishing from May 21 to March 31, but the season was reduced in 1911 to May 15 to October 30. Winter fishing was resumed in 1915.

From 1923 to 1925 and again from 1938 to the present, the opening of the season has been postponed until June 1.

These variations in the amount and type of gear, in the length of season, and in the size limits have resulted in variations in the catch. It is therefore difficult to evaluate the statistics and to determine whether the changes in the catch are the result of changes in the fish population or merely in the regulations and methods of capture. The major trends in production have been so pronounced, however, that there can be no question that the fish population has actually changed.

Changes in the Fish Population

Catch statistics (Tables 2 and 3) indicate that the species composition of the catch has changed markedly since commercial fishing first started. Pierre Gaultier, Sieur de La Verendrye, one of the first white men to explore Lake of the Woods recorded that in 1732 the lake was teeming with lake sturgeon and lake whitefish (Burpee, 1927). Evermann and Latimer (1910) stated that when commercial fishing started, Lake of the Woods

Table 2.—*Average annual commercial catch (thousands of pounds) in the Minnesota waters of Lake of the Woods, 1888–1946*

Years	All species	Lake sturgeon	Lake whitefish	Pike	Yellow pikeperch	Yellow perch	Sauger
1888–89	180	76	40	20	50	–	–
1890–94	1,461	830	257	136	285	–	–
1895–99	1,101	682	169	70	226	–	–
1900–04	393	93	101	48	155	–	–
1905–09	548	63	150	122	210	–	–
1910–14	1,315	370	102	312	440	1	–
1915–19	1,516	12	72	329	425	5	–
1920–24	1,148	3	33	277	502	8	–
1925–29	1,678	1	21	209	589	16	46
1930–34	2,107	1	13	231	782	46	207
1935–39	1,971	–	6	198	640	111	262
1940–44	1,543	–	3	119	455	18	60
1945–46	1,122	0	1	88	357	12	41

Table 3.—*Average annual catch (pounds) per pound net in Minnesota waters of Lake of the Woods*

Years	Number of nets	Lake sturgeon	Lake whitefish	Pike	Yellow pikeperch	Sauger	All species
1888–1889	7	10,000	5,500	2,750	6,875	–	25,125
1890–1894	65	14,500	5,134	2,590	5,905	–	28,129
1895–1899	129	3,912	1,143	461	1,397	–	6,913
1900–1904	71	1,261	1,436	682	2,250	–	5,629
1905–1909	61	1,074	2,755	2,085	3,697	–	9,611
1925–1929	41	17	376	920	2,939	169	7,929
1930–1934	60	14	220	752	5,173	734	9,647
1935–1939	60	12	60	765	3,713	751	7,877
1940–1944	50	10	34	593	1,753	239	6,129
1945–1946	36	[1]	14	422	1,017	91	6,384

[1] Sturgeon placed on protected list in 1941.

was the greatest sturgeon pond in the world and, until 1900, sturgeon comprised over half of the annual commercial catch. In the last decade of the past century over 7.5 million pounds of sturgeon were taken. Several of the old-timers say that these figures were low since large numbers were taken for caviar and the carcasses were thrown on shore to rot. In the 47 years since the turn of the century less than a million pounds have been taken, and since 1920 only 25,000 pounds have been reported. Only seven sturgeon were seen by the author from 1939 to 1943. In 1941 the sturgeon was put on the protected list.

The lake sturgeon began to decline by 1900 and more of the fishing effort was directed toward other fishes, particularly lake whitefish and yellow pikeperch. Whitefish production began to decline in the Minnesota waters about 1910, but the decline was not as sharp and decisive as was that of the sturgeon. In the Minnesota waters the whitefish has been of little importance as a commercial fish since 1920. There has even been a steady decline in the catch since that time, with the annual catch dropping from about 40,000 to 1,000 pounds. In the Canadian waters of the lake, the whitefish has held up fairly well, although the decline is clearly evident in Canadian fishery statistics.

Production of yellow pikeperch was maintained fairly well until 1937 when a continued decline started (Carlander, 1945a). The catch of pike declined about 70 percent in the last 30 years (Table 2), but the drop was not as sharp as with the sturgeon and whitefish.

Early statistics do not include the saugers and yellow perch, but there is some evidence that these fishes have increased since commercial fishing began. Although Evermann and Latimer (1910) listed the sauger as "not common," it is now one of the most abundant fishes in the lake. These authors further referred to the yellow perch as "common", while it would surely be classed as abundant now. It is possible that the gear used by Evermann and Latimer did not take these species in abundance and that saugers and perch were more abundant than they indicated.

Some of the species which have not been subjected to much commercial fishing have also changed in abundance. Although Evermann and Latimer (1910) listed both the goldeye and the mooneye, *Hiodon tergisus,* as common, goldeyes are now rare and there are no recent records of the mooneye. Some of the older fishermen say that the goldeye began to disappear in 1923 and that at about the same time the tullibee, *Leucichthys artedi tullibee,* began to increase in abundance. Fishery statistics are not complete enough to follow the changes in numbers of tullibee, which have been subjected to heavy commercial exploitation some years and have been unmarketable in other years because of the abundance of *Triaenophorus* parasites (Carlander, 1945b).

The longnose sucker and the quillback have decreased in abundance since 1910. Only a few longnose suckers are seen each year now, although Evermann and Latimer (1910) listed them as abundant. Evermann and

Latimer (1910) listed the white sucker, *Catostomus commersonnii,* as less abundant than the longnose sucker. They are now the more abundant species. Quillbacks are still occasionally taken in numbers but they certainly could not be listed as "one of the most abundant fishes in this lake" (Evermann and Latimer, 1910).

Overfishing as a factor in population changes.—Excessive fishing was probably responsible for the virtual disappearance of the lake sturgeon in Lake of the Woods. Evermann and Latimer (1910) stated, "The great decrease in the sturgeon catch of the Lake of the Woods is without doubt chiefly due to overfishing, although it is claimed by local interests that recent years show a slight increase in the catch, and the statistics sustain this contention. There is no evidence that the sturgeon have actually increased in abundance. This increased catch is more likely due to closer fishing rather than to an actual increase in the abundance of the species." The increased catch to which Evermann and Latimer referred, from 36,583 pounds in 1906 to 88,042 pounds in 1908, was followed by a drop to 34,487 in 1909. After 1915, the annual catch only once reached 10,000 pounds. Fishing pressure on the sturgeon was extremely heavy during the 1890's. In 1895 and 1896, 193 pound nets were used in the Minnesota waters of the lake—over three times the number in use since 1925 (Table 1). During this same period the fishing intensity was also at its greatest in the Canadian waters, with 100–127 pound nets in use (Evermann and Latimer, 1910).

The disappearance of the lake sturgeon following intensive exploitation is a phenomenon that has been observed in many American waters. Forbes and Richardson (1920) reported that prior to 1900 the lake sturgeon was disappearing from the Great Lakes and from the Illinois and Mississippi Rivers. In referring to the Great Lakes fisheries, Van Oosten (1937) stated, "The lake sturgeon, once considered a nuisance in the fishermen's nets, due to its abundance, and recklessly piled like cord wood on shore and burned, has now become a museum curiosity." In a later paper (Van Oosten, 1939) he commented further, "Here was a species whose disappearance was not the result of wasteful utilization, but of sheer wanton destruction." Even in the Canadian waters, Bajkov (1930) found the sturgeon disappearing and stated, "Slow-growing and seldom spawning before the age of twenty-five years, the sturgeon in Lake Winnipeg have to be rigidly protected, if extinction is to be prevented."

The intensive fishing during the last decade of the last century not only affected the lake sturgeon population, but apparently also reduced the other principal species. Catches of lake whitefish, pike, and yellow pike-perch were low during the years 1900–1904 not only in total production (Table 2) but also of catch per pound net (Table 3). These species appeared to recover, however, and did not follow the trend of the sturgeon.

The decline of the whitefish from 1910 to the present may also have been the result of heavy fishing. In the Great Lakes, the abundant whitefish was greatly reduced in numbers following intensive fishing (Van

Oosten, Hile, and Jobes, 1946). Likewise in Lake Manitoba the whitefish, which supported a heavy fishery in the closing years of the last century, is now practically extinct (Hinks, 1943). That the depletion of the whitefish in Lake of the Woods was the result of overfishing is not so clear as in the case of the sturgeon. There was apparently some increase in the amount of fishing from 1910 to 1920, but the fishing intensity does not seem to have been as great as in the 1890's, a period after which the whitefish recovered. Furthermore, longnose sucker, goldeye, and quillback, which were not subject to extensive exploitation declined at about the same time as the whitefish. Such declines suggest that the environment changed and became less suitable for these species.

Environmental change as a factor in population changes.—Probably the principal causes of the environmental changes in Lake of the Woods were the lumbering operations and pulp-mill pollution. Heavy lumbering operations began about 1906 and much of the immediate watershed was stripped of its forest cover. In 1907, large paper mills were built at International Falls and Port Francis about 80 miles up the Rainy River from the lake (International Joint Commission, 1916). The pulp wastes have destroyed spawning beds the entire length of the river and have even had their effects some distance into the lake, but damage to the lake proper is slight as yet.

The destruction of the spawning beds in the Rainy River was probably responsible to a considerable extent for the decline of several species of fish. Evermann and Latimer (1910) reported in reference to the lake sturgeon, that, "The principal, if not the only, spawning ground is the Rainy River." The decrease in the sturgeon population came before the pollution destroyed the spawning beds in the river, but the lack of spawning beds may have contributed to the later stages of the decline. Longnose suckers and whitefish probably also spawned extensively in the Rainy River and the destruction of the spawning beds may have contributed to their reduction which occurred from 1915 to 1925, 10 to 20 years after the pollution started.

Yellow pikeperch also spawned in the Rainy River and many people blamed its decline on the pulp-mill wastes. However, the decrease in this species has come only in the last 10 years, or much later than might be expected if the cause were pollution (Carlander, 1945a). Mill wastes in the river may reduce the reproductive success of the pikeperch, but they are probably not directly responsible for the recent depletion since the lake itself has always been the important spawning ground for this species.

In an attempt to determine the relationships between fish production and various environmental factors, a study was made of the correlations between the abundance of year classes of the principal Lake of the Woods fishes and rainfall, temperature, and water levels.[3] From the analysis of

[3] Carlander, Kenneth D., Ms. An investigation of Lake of the Woods, Minnesota, with particular reference to the commercial fisheries. Minn. Dept. of Conserv., Bur. Fish. Research, Invest. Rept. No. 42, 456 pp., 184 tables, plus 4 appendices, typewritten, 1942.

the age composition of 1,556 saugers collected in 1936, 1937, 1939, 1940, and 1941, the relative abundance of saugers in various year classes from 1931 to 1937 was estimated. The 1934 year class appeared to be the most abundant, and the others in order of abundance were 1932, 1935, 1931, 1936, 1937, and 1933. There was found to be a significant positive correlation ($r = 0.84$; $p = 0.017$) between the abundance of the saugers in a year class and the rainfall during June of the year in which they hatched. Doan (1941, 1942) demonstrated a correlation between turbidity and the abundance of saugers in Lake Erie suggesting a greater survival of young saugers when the waters were more turbid. It is possible that the rainfall would increase the turbidity and that the correlation found at Lake of the Woods was the same as that found by Doan. It may also be that the rainfall brought in additional nutrient materials at a crucial period resulting in greater growth and survival, or the correlation may not indicate cause and effect at all.

Langlois (1941) stated that silting and turbidity in Lake Erie were responsible for the decreased populations of lake whitefish, shallow-water ciscoes, perch, and pikeperch, but Van Oosten (1948) demonstrated that these factors could not be responsible for this depletion. That silting was not a major factor in modifying the fish population at Lake of the Woods is indicated by the fact that two of the species that have almost disappeared, the goldeye and the quillback, are normally found in the Mississippi River where the turbidity is much greater than in Lake of the Woods.

Selective Fishing as a factor in Population Changes.—In compiling the catch statistics for saugers and yellow perch (Table 2), it was noted that the catches were particularly high during the years 1931–1937. Talks with the commercial fishermen and examination of the violation records of the Minnesota Conservation Department indicate that large amounts of small-mesh gill net (3- to 3¾-inch mesh, stretched measure) were being fished illegally during this period. These small-mesh nets will catch many more perch and saugers than can be caught in the legal 4-inch mesh. Since very few small-mesh gill nets were fished after 1937, the resulting decrease in the catch of saugers and perch probably does not indicate any decline in the abundance of these fishes.

Selective fishing may be one of the important factors affecting the present abundance of the fishes. The 4-inch-mesh gill nets are particularly adapted for capturing legal-sized yellow pikeperch, *i.e.* over 15 inches, fork length. Out of 4,206 pikeperch measured from these gill nets, 84 percent were between 15 and 18 inches long. Yellow perch and saugers rarely reach a size to be properly gilled in these nets, and those taken are usually caught by their teeth or otherwise accidentally entangled.

Experimental fishing with small-mesh nets in 1939–1941 indicated that the saugers and yellow perch were much more abundant than the commercial catch would indicate. In the small-mesh gill nets (2 to 3½ inches, stretched measure), the saugers comprised at least 20 percent of the total catch, as compared to 7 percent of the total catch of commercial

nets. The perch also made up at least 20 percent of the catch in the experimental nets compared to 1 percent of the catch in commercial nets. In the experimental nets, yellow pikeperch contributed less than 10 percent to the catch whereas they made up about 30 percent of the take in commercial nets. These figures are not entirely comparable because the greater size range of the pikeperch means that a smaller percentage of the population is taken in the smaller-mesh gill nets. However, it seems obvious that the commercial catch of the saugers and yellow perch could be increased at least fourfold without imposing as heavy a fishing intensity on those species as is now directed toward the pikeperch. The present fishing practices favor the survival of yellow perch and saugers over the pikeperch and permit them to utilize a greater portion of the basic productivity of the lake, thereby increasing the competition with the latter species.

It is a generally accepted principle of fishery biology that the productivity of each body of water is rather definitely limited by its fertility, but a certain level of fertility can yield more pounds per acre of those fishes which feed on plankton or bottom organisms than of those that are piscivorous and have longer food cycles (Thompson, 1941). There is little evidence of any change in the carrying capacity of Lake of the Woods since commercial fishing first opened. The average catch per pound net of all species combined (Table 3) has not varied greatly except for the first few years of fishing. It has been shown that during these first few years, fishing was excessive and more than the sustainable yield was apparently removed. Also at that time much of the catch consisted of lake sturgeon, a fish with a fairly short food cycle.

Since the carrying capacity is limited, a great increase in one species must be accompanied by a corresponding decrease in other species occupying a similar ecological position. The increased survival of yellow perch and saugers may therefore be a factor in the decline of yellow pikeperch. Furthermore, a comparison of the food habits (Table 4) of the three species indicates that perch and saugers are direct competitors of the pikeperch for food. The yellow perch appears to be more insectivorous than the pikeperch and the sauger to be more piscivorous, but the principal items of food for the three species are the same. During at least part of the year, the saugers and perch are bottom feeders to a greater extent than the pikeperch and are more frequently taken in deeper water. The competition, therefore, may not be as severe as indicated by the food studies alone. In studies on Norris Reservoir the saugers were almost invariably found in deeper water than the pikeperch during the summer months (Cady, 1945; Dendy, 1946). In some Wisconsin lakes, Hile and Juday (1941) found most yellow perch in deeper water than the yellow pikeperch.

Lake of the Woods is shallow and not thermally stratified, but a fairly well defined difference was found in the distribution of the saugers, yellow perch, and yellow pikeperch during the summer months of 1941 (Table 5). The latter species was taken most abundantly in nets floated so that they

extended from the surface to a depth of 8 to 12 feet, not reaching the bottom. Saugers and yellow perch were most frequently taken with nets set on the bottom in 18 to 35 feet of water, where the pikeperch were least abundant. The separation of habitat was not so great as to eliminate competition, but it does indicate possibilities for selective fishing.

It seems likely that the selective fishing and the resulting increased

TABLE 4.—*A comparison of the principal items of food eaten by yellow pikeperch, saugers, and yellow perch in Lake of the Woods, 1939–1941*[1]

[Expressed as the percentage of stomachs containing various items of food]

Food item	Yellow pikeperch over 150 millimeters long	Saugers over 100 millimeters long	Yellow perch over 150 millimeters long
Cambarus sp.	8.0	1.0	55.9
Ephemeroptera	15.8	10.8	20.9
Chironomidae	15.5	0.3	6.2
Total invertebrates	39.5	12.7	89.3
Leucichthys sp.	7.1	3.0	–
Perca flavescens	26.7	33.7	7.0
Minnows	24.0	38.4	17.8
Total fish	61.0	90.9	24.8

[1] Based upon the analysis of stomachs from 450 yellow pikeperch, 297 saugers, and 129 yellow perch

competition from the unutilized fishes is one of the important factors in the fish-population changes. Small ponds frequently become overcrowded with undesirable species which replace the more desirable game fishes. Bennett (1943) stated, "In these cases special effort must be made to crop the less desirable species much more heavily than the others, espe-

TABLE 5.—*Average number of fish taken in 24 hours in 800 square feet of gillnet (3- to 4-inch mesh) at various depths in Lake of the Woods, June to September, 1941*

Depth (feet)	Number of sets	Number of fish		
		Yellow pikeperch	Sauger	Yellow perch
8–12	71	1.3	1.3	2.9
12–18	79	1.2	3.5	2.9
18–35	362	0.8	5.7	4.6
35–40	26	1.0	4.9	0.0
Floated	75	3.0	1.8	0.1

cially among the younger broods." Viosca (1930) told of a Louisiana law setting a minimum size limit of 16 inches on all fresh-water catfish taken commercially. The average size of the catfish gradually declined and the relative abundance of bullheads (*Ameiurus* spp.) and eel cats (*Ictalurus anguilla*) which seldom exceed the 16-inch size limit increased. Viosca

stated "The law gives relatively greater protection to these two less desirable species, and competition for the limited food supply does not rest." Eschmeyer and Haslbauer (1946) recommended winter gill netting in Norris Reservoir to utilize the saugers which were not being taken in relation to their abundance.

It is suggested that better management of the Lake of the Woods fisheries could be secured if some means of capturing and utilizing more saugers and yellow perch were developed, so that these species could be exploited on an equal basis with the yellow pikeperch.

Conclusion

It is recognized that the factors discussed above do not explain all of the changes that have occurred in the fish population of Lake of the Woods. The practical disappearance of the goldeye, longnose sucker, mooneye, and quillback was probably only partly the result of pulp-mill pollution, and surely cannot be blamed upon either overfishing or selective fishing. Some other environmental change was probably involved. It appears likely, however, that overfishing, selective fishing, and environmental changes associated with pulp-mill wastes have at various periods influenced the fish population and changed its species composition.

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SURVIVAL OF TROUT IN STREAMS

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ABSTRACT

In spite of extremely heavy expenditures for rearing of hatchery fish, the angling continues to decline. Millions of fish are wasted each year because of lack of facts on how best to utilize properly the product of hatcheries.

Survival studies have indicated that under natural conditions, wild brown trout suffer tremendous natural mortalities amounting to 85 percent in the first 18 months of life. Overwinter mortalities averaged 60 percent over a 5-year period. Variable survival conditions rather than the number of young produced in any year, determine the number of fish that later reach catchable size.

Survival studies of hatchery-reared trout indicated heavier losses than with naturally spawned fish. Creel-census returns from a number of different waters are presented to support this fact.

The conclusion is reached that the angling public must be made aware of the basic economics of hatchery operation, its costs, successes, and failures in order that the field of fishery management again may move ahead.

INTRODUCTION

Millions of dollars are spent annually on the rearing and planting of trout throughout the United States. In spite of these efforts, the angling continues to decline. Most states since the war have suddenly found themselves facing new hordes of customers who are placing a serious drain on their fish resources. The net effect of the increased pressure is less fish per individual. With more fishermen to share the catch, there are less fish to be had per person. This condition has brought protest and criticism to conservation departments and the cry, as usual, is for larger and better fish hatcheries.

Heavy losses of hatchery-reared fish in streams following planting have been made known by much fact-finding work over the past 10 years. Millions of fish have been planted in waters to which they were unsuited and in which the effort was largely wasted. For example, in the three Pacific Coast states, millions of eastern brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) were planted in coastal waters without evident result. In many of the inter-mountain states, exotic species like eastern brook and brown trout, although doing very well in certain waters, have frequently failed because of lack of knowledge of where to plant these species. In many waters, native stocks still continue to bear the

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brunt of the angling in spite of continual heavy plants of exotic hatchery fish.

The demand for larger and better fish hatcheries is only natural. The public witnessed the stocking of thousands of barren waters throughout the United States and concluded from the fine fishing produced that the answer to the present scarcity of fish must be more fish hatcheries. The average sportsman still believes this firmly and we have no one to blame but ourselves for his attitude. We looked upon hatcheries as the simple, easy panacea for all our angling ills for years and spread the dogma far and wide.

We know fairly well now what to expect in many types of waters in terms of returns to the creel from a planting of any given number, size, or species of fish and it is my purpose here to present a summary of facts pertaining to the survival of both wild and hatchery fish planted in streams. It might be well first, to consider survival problems in populations of wild trout in order to obtain a basis for comparison with survival of hatchery-reared fish.

Survival of Naturally Propagated Brown Trout

In work by Needham and Slater (1945) done at Convict Creek in eastern California over a 5-year period, it was determined that on the average, each naturally spawned yearly brood of brown trout decreased about 85 percent in the first 18 months of life. In other words, out of every 1,000 2- to 3-inch fingerlings produced annually, only some 150 survived to become yearlings. This fact alone indicates that extremely heavy mortalities occur in wild trout populations.

From this same work, it was also found that the average overwinter loss of all brown trout, regardless of size, was 60 percent and was evidently directly correlated with severity of winter conditions. Convict Creek is a typical, small, high-mountain trout stream averaging about 15 feet wide. The area in which the work was done lay in a meadow at an elevation of 7,200 feet. The stream was, therefore, subject to severe climatic conditions in the winter. Winterkills of trout were caused by heavy snow and ice conditions. In one instance, over 250 trout were found smothered to death under a single snow drift that had broken off into the stream bed. On waters draining areas of milder winter climates, heavy floods doubtless cause parallel heavy mortalities.

Over the 5-year period of the work on Convict Creek, natural reproduction alone contributed an average of 2,750 fingerling brown trout per mile of stream each year (range from 4,905 in 1940 to 1,714 in 1939). Only 16 percent of the 1939 fingerlings were lost over the winter of 1939–40 whereas in contrast, 85 percent of the 4,905 fingerlings were lost over the winter of 1940–41. In terms of fish available to anglers, the 1939 brood, by reason of its higher overwinter survival, contributed more fish to anglers than the 1940 brood which started with peak numbers but which was decimated by environmental factors. Variable survival conditions,

rather than the number of young produced by natural spawning in any given season, largely determines the number of fish that later reach catchable size.

It was determined also that the survival rate of wild brown trout fingerlings was much higher than that of fish of the same species planted from hatcheries.

Wild populations of brown trout were studied in two closely adjacent sections of Convict Creek, one of which was open to fishing while the other was closed to angling. Fish populations were removed by diversion of the water and pumping the stream bed dry by means of a small portable pump.

The fished section averaged only 3,818 trout or 83.3 pounds per mile, while the section closed to angling averaged 5,438 fish or 360.3 pounds per mile. If the population of the section closed to fishing is assumed to be a maximum standing crop, it would be necessary to plant 277 pounds of trout per mile to bring the population in the open section up to that of the closed section. This poundage would be equivalent to about 2,700 6-inch fish per mile and theoretically, at least, stocking as heavy as this would not be in excess of the numbers that could be supported naturally by Convict Creek.

With the annual natural production of young so tremendous and with the heavy subsequent losses under natural conditions, it is apparent that trout angling is definitely a "luxury" trade. Each fish that survives to the angler's creel represents the end product of a considerable stream area, or to put it another way, the lone survivor of many hundreds of other fish that never matured to be caught. The older and larger the fish caught, the higher are the losses of fish behind that individual. It is time that we inform the average fishermen concerning some of these things if we are to get their cooperation in killing less fish so they can catch more fish.

Another interesting fact to come out of the Convict Creek work was that a survival of only 30 female brown trout of spawning age per mile of stream would be required to produce the greatest number of young fish per mile that this stream could support in any year. Herein lies a strong argument for angling regulations which will assure adequate escapements of brood trout necessary for the recruitment of naturally spawned stream stocks.

Survival Data on Hatchery-Planted Fish in Streams

It might be well to review for a moment some of the available information on western trout streams wherein attempts have been made to determine survival following planting and to present ratios of the number surviving compared to numbers planted.

The 1938 creel-census returns from the Kern River in California reported the capture of 5,579 rainbow trout, 73 brown trout, and 58 brook trout. Between 1934 and 1938, 275,000 brown trout had been planted in the stream. On the basis of the 1938 returns, the ratio of number planted in previous years to the number taken in 1938 was 1:3,767. In Squaw

Creek in northern California between 1930 and 1936, 130,000 brown trout had been planted. In 1937, when a creel census was made on that stream, 2,497 rainbow trout were taken but only 7 brown trout and no eastern brook were taken. The ratio of brown trout planted to numbers caught was 1:18,571 (Randle and Cramer, 1941). Here again is the old story of native stocks maintaining the burden of the angling in spite of heavy plantings of non-native species. Wild, naturally spawned rainbow trout furnished over 97 percent of the fish caught by anglers in Squaw Creek.

Needham and Slater (1944) carried on survival experiments with hatchery-reared fingerling brown trout at Convict Creek and obtained a survival of 63.7 percent for fingerlings averaging 1.2 to 1.5 inches long. Larger rainbow trout fingerlings ranging from 2.8 to 3.7 inches in length under more severe competition by wild trout produced a gross survival of 46.6 percent. These results were obtained over the summer growing season only when ideal water conditions prevailed for the growth and development of the fish. But even so, losses ranged from about 45 to 65 percent in periods varying from 89 to 151 days. Add overwinter losses to summer losses, and it is apparent that plantings of such fish in mountain streams are largely ineffectual.

These results do not indicate futility of plantings any more strongly than those obtained by many workers. Survivals of less than 1 percent for 1- to 3-inch fingerlings are the usual story while, under ideal conditions, plantings of legal-sized fish during open seasons may produce returns as high as 80 percent. I have no intention here of citing the work of various individuals and agencies that have been studying this problem. Here I am concerned more with the applications of existing facts than with the means of discovering them. Schuck (1948) gave an excellent review of the whole problem of the survival of hatchery-reared trout. It is clearly indicated in his paper that one major reason for the low recoveries is the inability of hatchery trout to survive for any length of time under natural stream conditions. He pointed out that one principal cause for this high mortality may be improper methods of feeding and rearing in hatcheries and recommended a critical evaluation of all hatchery procedures with a view toward modification of those which limit a trout's ability to survive.

It is true that improvement of our hatchery techniques is one of our major concerns, but we have a parallel problem in public relations. For years we have been blithely putting out lists of streams and lakes stocked. It is time now that we consign these lists to the waste basket and begin to educate the public as to what we can and cannot do with hatchery fish. As was pointed out by Taft (1947), "The principal barrier to further progress is the unreasoning and abiding faith of our customers in the planting of fish under all conditions, at all times, and in every water." Further progress will become possible only when the facts are made known to the fishing public and applied in our management programs.

We all know we are going to need fish hatcheries. The real problem

is one of using the product in such a manner as to get the greatest possible return to creels of the anglers at the least possible cost. With our rearing operations now costing us around 50 cents per pound of fish for food alone, it would seem desirable to spend somewhat more money on fact-finding work to learn what we are getting for our money and reduce a bit the rearing and planting operations where the values are questionable. It seems that some money now going into propagation might well be spent on such items as stream and lake improvements, creel-census work, and research. The Oregon Game Commission is obtaining excellent cooperation from a number of sportsmen's clubs in creel-census work. The anglers themselves are glad to help and such work does a lot of good in educating the fisherman on the facts with respect to survival of trout in terms of cost-and-catch figures. If we can rear and plant legal-sized trout for say 20 cents apiece and if only 25 percent survive to be caught, the end cost becomes 80 cents each in the creel. This is expensive business. On the other hand, if by better rearing and planting under conditions more conducive to survival, an 80-percent return is obtained, the end cost in the creel is reduced to 25 cents per fish. Even this cost per fish would permit catching only 12 such fish on a 3-dollar resident license fee. If more than 12 such fish are taken, it is done at the expense of other anglers.

It is a well known fact fully demonstrated by creel-census studies, that over 80 percent of the fish taken in any given watershed are taken by less than 25 percent of the anglers. Since this is true, reduction of seasons and of bag limits to say a 60-day season and five fish, hurts the average fisherman very little; the person it really affects is the expert, the rod artist who can take fish easily at almost any time under difficult conditions. Herein lies a potent argument for more severe restrictions to secure greater spread of available fish among greater numbers of anglers.

To get back to our main thesis, the basic economics of hatchery costs and survivals must be understood by the license holders, and once they understand the problem, the field will again move forward.

There are many opportunities for management by such means as stream and lake improvement, trash-fish control, improvements to aid natural propagation, and fertilization of lakes to increase fish production. Once tested methods are available and once we have our hatchery programs in proper balance with other activities, fishery management will become a reality.

It is high time that we examined our entire fish-cultural programs with a critical eye toward applying facts presently available. Fish hatcheries are not the whole answer; they are only part of the answer, and the most expensive part at that. We must place the facts before the sporting public so that they, too, will begin to understand the nature of the critical problems facing us in the maintenance of game-fish populations. If the public is informed, it will help, instead of hinder, the application of new discoveries. No program can succeed without public support.

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THE POPULATION OF YELLOW PIKEPERCH (*STIZOSTEDION V. VITREUM*) IN SPIRIT LAKE, IOWA

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Abstract

A decline in gill-net catches of adult yellow pikeperch of the spawning runs and reduced catches by anglers in Spirit Lake, Iowa, during the past several years prompted the Iowa Conservation Commission to estimate the available stock in the lake by a tagging experiment. A total of 550 adult yellow pikeperch was tagged. In a subsequent creel census of fishermen from May 15 to November 1, 1947, 157 tagged fish were recaptured and 8,719 untagged yellow pikeperch were caught. By means of the Peterson formula, the population of adult yellow pikeperch in the lake was calculated to be 30,544 as of May 15, 1947. This appraisal indicated depletion. Management practices were modified to favor return of the yellow pikeperch to its former abundance.

Introduction

One of the most important problems confronting biologists and wildlife managers today is that of regulating the harvest in such manner that sustained or increased yield can be obtained. The estimation of fish populations in public waters is now recognized as an indispensable part of the information on which the improvement of carrying capacities for desirable species of game fishes must be based. As a consequence, increasing numbers of lakes and streams are now subject to periodic population study as well as biological survey, creel census, and other investigations.

The yellow pikeperch, *Stizostedion v. vitreum* (Mitchill), is considered one of the principal game fishes of Spirit Lake; however, an obvious decline in catches during the past decade has caused much concern among the sport fishermen and to the Iowa Conservation Commission. In order to obtain additional data pertinent to the status of the stock, an estimate of the population was made by means of the tagging method. Steps toward better management of the species have been taken as a result of this investigation.

Spirit Lake, Iowa's largest inland body of water, covers a total of 5,684 acres exclusive of many connecting smaller lakes and sloughs. It is a shallow, eutrophic lake of glacial origin, with a maximum depth of about 25 feet, and an average depth of approximately 12 feet. The water is usually clear, although slight blooms of blue-green algae occur occasionally during the late summer and fall. The littoral zone of the lake is usually well vegetated with such submerged species as *Potamogeton richardsonii*,

P. illinoensis, P. natans, and *P. pectinatus.* Emergent stands of *Scirpus acutus* are common, although like the submerged forms they have been reduced during the past year by the ravages of carp, and perhaps other causes.

Spirit Lake has long been noted for its splendid sport fishing for the yellow pikeperch. As mentioned above, however, catches have declined progressively for the past 10 years. Creel-census records of the past 4 years show few of this species in the fisherman's catch.

A hatchery for the yellow pikeperch has been operated by the Iowa Conservation Commission at Spirit Lake for the past 40 years. Spawn for the hatchery is obtained largely from spawning-run fish captured in Spirit Lake and the adjoining Okoboji Lakes by gill-netting. In order to estimate the population of yellow pikeperch in Spirit Lake a portion of the 1947 run was selected from the gill-net catches for tagging. These fish were released at various points in the lake. This method was used because of its economy and the ease in taking relatively large numbers of adult fish in a brief period of time. The ratio of tagged and untagged fish in the subsequent creel census during the open season formed the basis for the population estimate. Thus, the plan is similar to that employed in recent studies conducted by Eschmeyer (1942), Thompson (1941), Stoudt and Eddy (1939), Ricker (1942), Miller and Bryan (1947), and other investigators.

Evidence of Depletion

Records of the catches made by gill-netting crews which operate for the State hatchery, kept since 1936, are fairly complete except for the years 1943 and 1944. The information on these records has been compiled and tabulated to show the average number of yellow pikeperch caught each night by each crew. The yearly comparisons of the catch of yellow pikeperch provided by the tabulations suggest astounding fluctuations in abundance over the period.

Usually four or five crews operate on Spirit Lake each spring. Each two-man crew is equipped with 800 feet of 2- to 2½-inch-mesh gill net (bar measure), which is set in shoal areas at dusk and lifted periodically throughout the night. Operations start shortly after the ice leaves the lake in late March or early April, and are concluded when sufficient spawn is obtained for the hatchery, or until the run tapers off. Since the number of crews has varied, the yearly totals of catches cannot yield comparable data; consequently, the catches (Fig. 1) compare the average number of yellow pikeperch caught per night per crew. The phenomenally large catch for 1936, with an average of 176 yellow pikeperch per night per crew, certainly denotes a higher population than during later years. The use of such data as indicative of relative abundance is subject to error, as pointed out by Van Oosten (1937), Ricker (1940), and Carlander (1945). However, possible distorting factors are largely eliminated here since we have had approximately the same fishing conditions, and the same number and

mesh size of nets, and sets have been made in about the same locations each spring. Thus the catch per unit effort provides comparable data and hence may be employed in the same manner as by Hile (1937). Therefore, it is believed that the data are adequate to demonstrate a decline in abundance of the yellow pikeperch. Without further evidence than the gill-netting records, it is difficult to explain the sharp decline in catches from

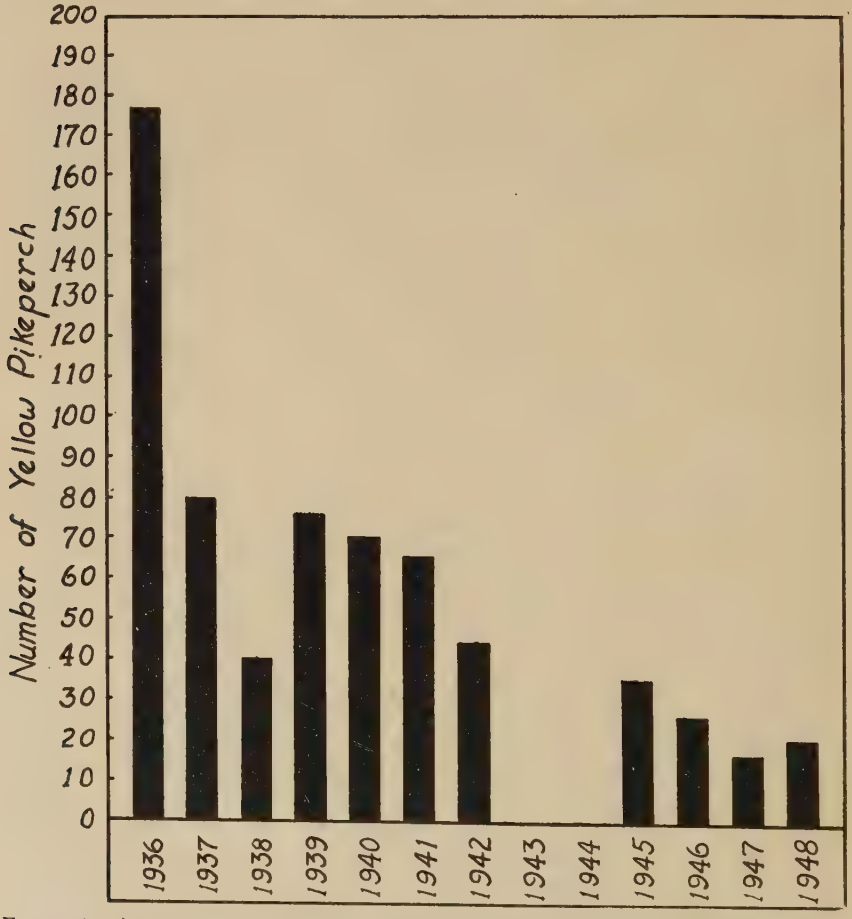

FIGURE 1.—Average number of yellow pikeperch caught per night per gill-netting crew on Spirit Lake, during spawning runs from 1936 to 1948 (no records for 1943 and 1944).

1936 to 1938. The catch in 1939 suggests the entrance of a strong year class into the spawning run; although no records are available to substantiate this judgment.

It is unfortunate that creel-census records are not available from 1936

to 1941; however, the recollection of guides and expert fishermen is that good catches were made almost every year prior to about 1943. A summary of the creel-census records from 1945 to 1948 is outlined in Table 1. Only the yellow pikeperch and yellow perch (*Perca flavescens*) are included in the summary. There was no significant variation in the number of anglers or in fishing effort during the 4-year period. The catch of yellow

TABLE 1.—*Partial summary of a 4-year creel census of Spirit Lake anglers*

Species	Number of fish taken in calendar year			
	1945	1946	1947	1948
Yellow pikeperch	876	19,508	8,719	6,520
Yellow perch	17,038	21,452	43,624	56,804

pikeperch was very poor in 1945 in comparison with 1946, but the catch of gill nets (Fig. 1) was higher in 1945 than in 1946. Also, the catch of yellow pikeperch by anglers in 1948 was lower than in 1947, although the gill-net take shows an increase in 1948. The difference in anglers' catches during 1945 and 1946 was due entirely to a phenomenally large hatch of yellow perch in 1944. These small perch served as prey for the yellow pikeperch and other predacious species until 1946. In 1947 and 1948 this 1944 year class of perch entered significantly into the anglers' catch (Table 1). As is commonly known, even though a suitable crop of fish may be present, if forage is too abundant sport fishing can be extremely poor and the inference drawn erroneously that the body of water is "fished out". Thus, information obtained from creel-census records concerning abundance of fish or fluctuation in population should be treated with caution. Where it is not possible to drain a lake or poison and actually count the fish, a population estimate may be determined by marking or tagging.

PROCEDURES IN THE TAGGING EXPERIMENT

A total of 556 adult yellow pikeperch was tagged from the net catches of the hatchery crews and from special 1½-inch-mesh gill nets (bar measure) set especially for small adults. The length distribution of the tagged fish (Table 2) includes the numbers tagged in each 30-millimeter size group, plus the number and percentage of each size group recaptured by anglers and reported in the creel census.

Tagging was carried out throughout the entire period of the spawning run from April 6 to April 26, 1947. An effort was made to distribute the tagged fish uniformly about the lake in order to increase the chances of random sampling at the opening of the fishing season on May 15. Several of the tagged fish were recaptured in hatchery gill nets set from 2 to 5 miles distant from the point of liberation. One moved 5 miles in 8 hours. Others were recaptured from ½ to 2 miles away in from 2 to 10

TABLE 2.—*Length distribution of tagged yellow pikeperch used in population estimate in Spirit Lake, number of recaptures, and percentage of recaptures in each size group*

Standard length (millimeters)	Total length (inches)	Number tagged	Number recaptured	Percentage recaptured
248–280	11.7–13.3	6	1	16.6
281–310	13.3–14.9	81	19	23.5
311–340	14.9–16.1	42	8	19.0
341–370	16.1–17.0	53	10	19.0
371–400	17.0–19.1	133	51	38.3
401–430	19.1–20.7	122	42	34.4
431–460	20.7–21.6	77	16	20.8
461–490	21.6–22.6	30	7	23.3
491–520	22.6–23.2	7	1	25.0
521–550	23.2–25.3	2	1	
551–580	25.3–26.6	1	1	
581–610	26.6–27.0	2	0	
Total		556	157	28.2

days. The data indicate that at this period, the yellow pikeperch moves about freely, and that the uniform dispersal of tagged fish is not so essential as in certain fishes, particularly the centrarchids.

Each fish was tagged with a number 3 metal tag. Standard length, total length, and weight were recorded for each fish tagged, and scale samples were taken for subsequent determinations of age and growth. The tags were attached firmly to the corner of the upper jaw, including maxillary and premaxillary bones, and efforts were made to tag only vigorous unscarred fish that had been recently caught. As soon as tagging was completed the fish were carefully returned to the quiet, windward shores of Spirit Lake. Of the 556 fish tagged, 3 were found dead prior to the opening of the fishing season. In the course of periodic checks of the leeward shores during the summer 3 more tagged fish were found dead. Therefore, all calculations are based on the assumed presence of 550 tagged yellow pikeperch at the start of the season, and the ratio of the tagged and untagged fish caught was determined from the creel census by 10-day intervals. The population estimate is based on the number of tagged and untagged fish caught from May 15 to November 1, 1947.

The method used for estimating the population is based on the procedure originally employed by Peterson (1896), and now followed more or less generally, although with many modifications and refinements depending upon the type of study being conducted. A recent publication by Ricker (1948), describes the various methods and statistical evaluations for different types of fish-population investigations. The methods described, and his studies of Shoe Lake in Indiana (1942) have been utilized to some extent in estimating the population of yellow pikeperch in Spirit Lake. The simple formula $P = \frac{AB}{C}$ is used, with P the population estimate, A the number of fish caught by the anglers, B the number of tagged fish in the lake (550), and C the number of tagged fish taken in the entire sample catch. Exploitation rate is determined by dividing the total recaptures by the total number tagged.

The data necessary for computing the population estimate were obtained from the intensive creel census (Table 3). The census was conducted by a census clerk with the cooperation of 13 boat liveries, the tackle stores,

TABLE 3.—*Total catch of yellow pikeperch* (A) *and recaptures of tagged fish* (C) *as determined from a creel census of Spirit Lake anglers during 1947*

[On May 15 there were 550 tagged fish in the lake. The last two periods were grouped due to the relatively small numbers of pikeperch caught]

Period	Total catch A	Recaptures C	$\frac{C}{A}$
May 15–May 24	2,839	41	0.0144
May 25–June 3	1,659	32	0.0193
June 4–June 13	1,425	25	0.0176
June 14–June 23	1,008	23	0.0228
June 24–July 3	754	11	0.0146
July 4–July 13	374	6	0.0160
July 14–July 23	120	3	0.0250
July 24–August 2	52	4	0.0770
August 3–August 12	49	1	0.0200
August 13–September 9	211	3	0.0140
September 9–October 31	228	8	0.0350
Total or average	8,719	157	0.026

guides, expert shore fishermen, and conservation officers. A considerable amount of publicity was given to the project by the press and radio. All census cards and data on recaptures were tabulated by 10-day intervals, starting May 15 (Table 3). The ratio $\frac{C}{A}$ for each period indicates the relatively uniform proportion of tagged to untagged fish, and serves as an aid in the estimation of the sampling error.

From the totals in Table 3 the population estimate is computed:

$$P = \frac{8{,}719 \times 550}{157} = 30{,}544$$

This is the estimate of the population of adult yellow pikeperch in Spirit Lake as of May 15, 1947. Since the average proportion of tagged to untagged fish is small, $\frac{157}{8{,}719}$ or 0.026 (Table 3), the convenient methods devised by Ricker (1937), for computing sampling error are utilized. The 95-percent fiducial limits are applied to the most likely variable, the recapture of tagged fish (C). Since Ricker's tables do not exceed 50 for the value of C, the formula for 95-percent confidence is used: limits $= C + 1.92 \pm 1.96 \sqrt{C + 1.0} = 134$ and 183. The corresponding population estimates are computed as:

$\frac{8{,}719 \times 550}{134} = 35{,}733$, the upper limit of estimate,

and $\frac{8{,}719 \times 550}{183} = 26{,}119$, the lower limit of estimate.

Obviously, *A*, *B*, and *C* are all subject to systematic error; consequently, any figure obtained is an estimate. Accuracy depends entirely upon the methods used and the extent to which the sampling is random. For example, the reliability of *A* is dependent upon the accuracy of the creel-census work, and the degree to which the contributions of all representative adult age and length groups in the sample catch are proportional to their relative abundance in the population. *B* is necessarily assumed as a constant. It is assumed that the effects of tagging and handling on survival and behavior are negligible, and furthermore, that the ratio of tagged and untagged fish in the census represents the true ratio in the lake. The greatest possibility for error of course, lies in *C*. If *A* and *C* are incomplete to the same degree, there is no prejudice to the population estimate. However, if a disproportionately high percentage of tags is reported, the estimate is too small and *vice versa*. Since the ratio *C/A* (Table 3) was fairly uniform throughout the 10-day periods the possibility of error from this source is probably minimal. Ideally, all size groups should be equally vulnerable to catch by the anglers. The percentages of tagged recaptures in each size group (Table 2) indicate that they were fairly uniform with the exception of those in the 371 to 430 millimeter range of standard length.

Effects of Tagging

There was some belief that tagging stimulated feeding and that the consequently greater number of recaptures produced a lower and biased estimate. Examination of the tagged fish recaptured did not support this belief, for comparative stomach analyses showed no difference in feeding between them and the untagged fish. Some of the tagged fish taken in late July 1947 showed evidence of irritation around the tag, and a slight loss in weight from the time of tagging. Others, the vast majority observed, exhibited no ill effects. Fish observed in the fall of 1947 or recaptured during the spring of 1948 showed the tags firmly in place with a slight overlap of maxillary tissue around the tag margins and no inflammation present.

During the 1948 gill-netting period and in the 1948 open season several records were obtained of the growth of tagged fish in length and weight (Table 4). Comparisons of these increments with information (not given here) on the rate of increase of untagged fish indicated that in most individuals the tagging exerted a retarding influence on growth.

Exploitation

The rate of exploitation indicates that 28.6 percent of the tagged fish were accounted for in the creel census. Since we assume that the same proportion of untagged yellow pikeperch was caught by anglers, a considerable drain on the stock is apparent. This harvest is not extremely heavy. It is conceivable, nevertheless, that this drain on the breeding stock is too severe. Another season or two of this intensive harvesting might

reduce this popular sport fish to a level from which reestablishment would be difficult. The species is in great demand by anglers, and several expert guides fish the numerous rock reefs and other likely areas very intensively throughout the summer. Furthermore, many expert shore fishermen make large catches along selected areas during all hours of the night, when a school is located. Summer survey investigations indicate that recruitment since 1944 has been meager—possibly just about balancing the mortality and takes of anglers.

TABLE 4.—*Growth of tagged yellow pikeperch over a period of approximately a year*

Tag No.	Sex	Date stocked (April 1947)	Weight (pounds)	Total length (inches)	Date recaptured (1948)	Increase of weight (pounds)	Increase of length (inches)
[1]1017	Male	25	1.0	14.7	April 16	0.4	1.7
[1]537	Female	18	2.4	19.0	April 10	0.8	0.6
[1]487	do.	13	3.0	21.2	April 7	0.2	0.5
[1]560	do.	17	4.2	22.2	April 16	1.8	1.2
[1]473	Male	13	2.4	17.0	April 16	0.2	1.5
974	do.	26	1.3	15.2	June 13	0.45	0.7
655	do.	20	0.9	13.3	June 11	0.6	1.6
1020	do.	26	1.1	14.0	June 19	0.15	2.0
838	do.	22	1.9	17.9	June 21	0.6	0.5
456	do.	15	2.1	18.6	June 14	0.65	0.3
582	do.	18	2.2	18.6	June 17	0.3	0.4
439	Female	15	2.6	20.2	June 28	0.5	0.7
465	do.	15	3.5	21.7	Oct. 25	1.5	1.7
905	Male	23	2.5	19.6	Oct. 7	0.2	0.3

[1]Recaptured during 1948 gill-netting, all others taken by anglers during 1948 open season

MANAGEMENT PROGRAM

In an experiment designed to evaluate the stocking of yellow pikeperch fry, the Iowa Conservation Commission has eliminated Spirit Lake from its fry-stocking program. This study has been in effect for the past 4 years. Yearly comparisons with lakes stocked with fry are determined by the summer survey work. Our evidence from this work supports the contention of numerous investigators that fry stocking is largely ineffectual in combating depletion. Carlander (1945) and Hile (1937) found no correlation between fry stocking and the later abundance of yellow pikeperch in Lake of the Woods, and Lakes Michigan and Huron.

Spirit Lake receives an annual allotment of fingerling yellow pikeperch from nursery lakes. Their numbers are so small, however, that their influence on the present adult population is slight. All stocked fingerlings are finclipped. Our present data indicate a high survival rate for these fish and the possibility of benefit from extending the nursery program.

The populations of black crappie (*Pomoxis nigro-maculatus*), yellow perch, black bullheads (*Ameiurus melas*), white bass (*Lepibema chrysops*), and largemouth black bass (*Micropterus salmoides*) have increased significantly during the past several years. These increases perhaps have produced interspecific relationships that limit natural reproduction and survival of the yellow pikeperch. Although W. F. Sigler (unpublished manu-

script) found little or no evidence of predation on the yellow pikeperch by white bass, he did believe that this lack of evidence was due to the scarcity of pikeperch of forage size in the lake. The white bass is noted for its extremely voracious habits and certainly would have taken young yellow pikeperch had they been abundant. Moen (unpublished data) has found considerable predation of yellow pikeperch spawn by the black bullheads, yellow perch, and carp (*Cyprinus carpio*).

Since it is apparent that adult yellow pikeperch have become depleted in Spirit Lake, new regulations established in 1948 were designed to favor this species and to provide a greater exploitation of the competitive species. These regulations include the elimination of size limits on the yellow perch, crappie, and white bass, advance of the open season on crappie to May 15 (formerly June 15), removal of the bag limit on bullheads, and a reduction in the daily catch limit on yellow pikeperch from 8 to 5. Carp control in Spirit Lake is badly needed, and extensive removal operations are underway at present.

It is possible that large-scale stocking of fry will be made in Spirit Lake in the spring of 1949 to fulfill a portion of the research project designed by R. M. Bailey in 1944 to appraise artificial propagation of this species.

Acknowledgement is given to T. E. Moen for assistance in tagging and to E. B. Speaker, Iowa Conservation Commission, Dr. Kenneth Carlander, Iowa State College, and Dr. W. E. Ricker, Indiana University, for many helpful suggestions, and also to the many sportsmen who have cooperated in the project.

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LENGTH-WEIGHT RELATIONSHIP OF THE MUSKELLUNGE, *ESOX M. MASQUINONGY,* IN LAKE ST. CLAIR [1]

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ABSTRACT

Data on the relationship between the total length and weight of the muskellunge, *Esox m. masquinongy,* based on measurements of 264 fish caught by anglers from Lake St. Clair are presented. The fish ranged in length from 30 to 54 inches and in weight from 6.5 to 37 pounds. The plotting of weights of individual fish against their respective lengths indicated a definite relationship between those measurements. Agreement was close between the data on muskellunge from Lake St. Clair and muskellunge (*Esox m. ohiensis*) from Chautauqua Lake, New York. Similar data on muskellunge (probably some *Esox m. immaculatus* and *E. m. masquinongy*) from scattered inland lakes of Michigan indicated that those fish may be slightly heavier than individuals from Lake St. Clair.

The muskellunge, *Esox masquinongy,* one of the largest fresh-water fishes, is highly prized by anglers. Lengths of more than 5 feet and weights upwards of 60 pounds have been recorded. Members of the species are distributed in a scattered fashion through inland lakes as far north as Lake Abitibi, Ontario, and eastward from the Lake of the Woods to the St. Lawrence Basin (Hubbs and Lagler, 1947). Fish in that area have been separated into two subspecies; the northern or Wisconsin muskellunge, *Esox m. immaculatus,* of the inland lakes and slow moving streams of northern Minnesota and Wisconsin, and the Great Lakes muskellunge, *Esox m. masquinongy,* from scattered areas of the Great Lakes and St. Lawrence Basin. A third subspecies, the Ohio or Chautauqua muskellunge, *Esox m. ohiensis,* is found in various localities through the Ohio River drainage as far south as the Cumberland River in Tennessee.

Lake St. Clair, astride the international boundary in the connecting waters between Lake Huron and Lake Erie, enjoys a reputation as one of the finest muskellunge waters in North America. From 1940 to 1947 the world record muskellunge taken by rod and reel were products of Lake St. Clair. The largest of these record breakers was a fish that weighed 62.5 pounds. In 1947, however, Lake St. Clair lost the title to a 64.5-pound muskellunge caught in Favil Lake, Wisconsin.

The area of Lake St. Clair on the United States side is about 180 square miles or roughly two-fifths of the total area. It has been estimated by

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local residents along the Michigan shore that as many as 1,000 muskellunge (*Esox m. masquinongy*) may be taken from the United States waters alone during a single season. Williams (1948) stated that 2,500 muskellunge were speared in Lake St. Clair during the winter of 1937–38. If such a take by spearing is the usual thing, and the estimate of the summer catch reasonable, the annual yield of muskellunge from the United States waters of Lake St. Clair is well over 3,000 fish. Even though such large numbers of muskellunge may be caught, the task of taking one is often tedious. Many anglers spend days on end, using a great variety of lures, and still go empty-handed. Spearing, too, can be tedious. This fishing is usually done by decoying the muskellunge into position with artificial decoys or live suckers. One may bob a decoy for hours and never see a muskellunge. Still the spear must be kept in readiness at all times. Once a prospective victim moves into position, the thrust of the spear must be accurate. There is no second chance. For a party to take more than one muskellunge a day, whether by spear or angling, is rare. Consequently a sizeable series of data on lengths and weights of that species is rather difficult to obtain.

During the summer of 1942, W. F. Carbine and the writer, then of the Michigan Institute for Fisheries Research, while conducting creel-census studies on Lake St. Clair, interviewed all operators of boat liveries along the Michigan shore of the lake. In the course of the interviews we found that Mr. Albert C. Gasow, Mt. Clemens, Michigan, sponsored an annual contest for anglers who caught muskellunge from boats owned by his livery. The contest, initiated in 1939, opened each spring when the first muskellunge was brought into the livery, usually in late April or early May, and was continued until the opening of the black bass season on June 15. As each fish was brought in, its total length was measured to the nearest quarter-inch and its weight determined to the nearest ounce. The data for each fish were recorded on a chart along with the angler's name and address and other information pertinent to the contest. Although other muskellunge were brought in later than June 15, they were not eligible for the contest and consequently their measurements were not recorded. The data on muskellunge entered in the contest consisted of measurements on 51 fish in 1939, 70 fish in 1940, 87 fish in 1941, and 56 fish in 1942—a total of 264 fish during the 4-year period. Grateful acknowledgement is extended to Mr. Gasow for the use of those data and for permission to publish them.

In the compilation of the length-weight data, the total lengths were placed in 1-inch classes. For example, the measurements 40.5, 40.75, 41.0, and 41.25 were grouped together, the central value being 40.88. The number of individuals in each interval together with the minimum, average, and maximum weights in pounds are listed in Table 1. There are, of course, no data for fish of a lesser total length than 30 inches, the minimum legal length for muskellunge in Michigan waters. The lengths of the fish ranged from 30 to 54 inches with corresponding weights of 6.5 and 36

TABLE 1.—*Numbers of Lake St. Clair muskellunge, grouped at intervals of 1 inch, together with the minimum, average, and maximum weights in pounds for each length group*

[Fish taken by anglers, 1939–1942, inclusive]

Total length (inches)	Number of fish	Weight (pounds)		
		Minimum	Average	Maximum
30.00–30.25	1	.....	6.50	.....
30.50–31.25	6	5.50	6.79	7.50
31.50–32.25	13	6.50	7.33	8.25
32.50–33.25	4	8.00	8.81	10.25
33.50–34.25	17	7.00	8.79	13.00
34.50–35.25	25	7.00	9.24	13.00
35.50–36.25	24	8.25	10.05	12.00
36.50–37.25	26	9.50	10.86	13.25
37.50–38.25	37	10.50	11.97	14.50
38.50–39.25	14	11.00	12.39	14.50
39.50–40.25	20	13.00	13.80	15.00
40.50–41.25	17	13.00	15.31	19.50
41.50–42.25	10	13.00	16.25	20.00
42.50–43.25	10	15.75	18.95	22.50
43.50–44.25	3	20.50	21.33	22.50
44.50–45.25	11	18.00	22.95	28.00
45.50–46.25	5	21.00	23.00	24.50
46.50–47.25	3	22.50	23.67	25.50
47.50–48.25	7	23.50	27.46	31.50
48.50–49.25	5	23.00	28.10	37.00
49.50–50.25	3	26.00	28.50	32.75
50.50–51.25	1	.....	32.75	.....
51.50–52.25	1	.....	33.00	.....
52.50–53.25	..	.....	.....	.....
53.50–54.25	1	.....	36.00	.....

pounds. However, the heaviest fish (37 pounds) was not the longest, but had a total length of 49 inches. The plotting of the weights of the individual fish, against their respective lengths indicated a definite relationship between the two (Fig. 1). Even though such a relationship does exist, there is a considerable variation in the weight of fishes of a given length group. For example, in the two groups centering around 33 and 34 inches, in which there were 17 and 25 fish, respectively, the weights varied from 7 to 13 pounds, a range of 6 pounds. In the larger size groups the variation in weight of fish of similar lengths was even greater. At 45 inches, for example, the weights of 11 fish fluctuated between 18 and 28 pounds, a range of 10 pounds. Furthermore, the heaviest fish of a given length group may be considerably lighter than a shorter fish. For example, the heaviest fish in the 36-inch group weighed only 12 pounds whereas fish grouped at 34 and 35 inches weighed as much as 13 pounds.

Occasional records in the literature mention lengths and weights of individual specimens, but there are few papers that give length-weight data on muskellunge comparable to those in the present study. Moore (1926) listed the lengths, weights, and ages of 20 muskellunge (*Esox m. ohiensis*) from Chautauqua Lake, New York. Those fish ranged in total length from 10.75 to 50.5 inches with corresponding weights of 0.19 to 36.0 pounds, respectively. Another series of data on muskellunge from Chautauqua Lake was that of Greeley (1938) who listed the age, length range, average lengths, weight range, and average weights for 189 muskellunge. Inasmuch as Greeley's data were grouped according to the age of the fish,

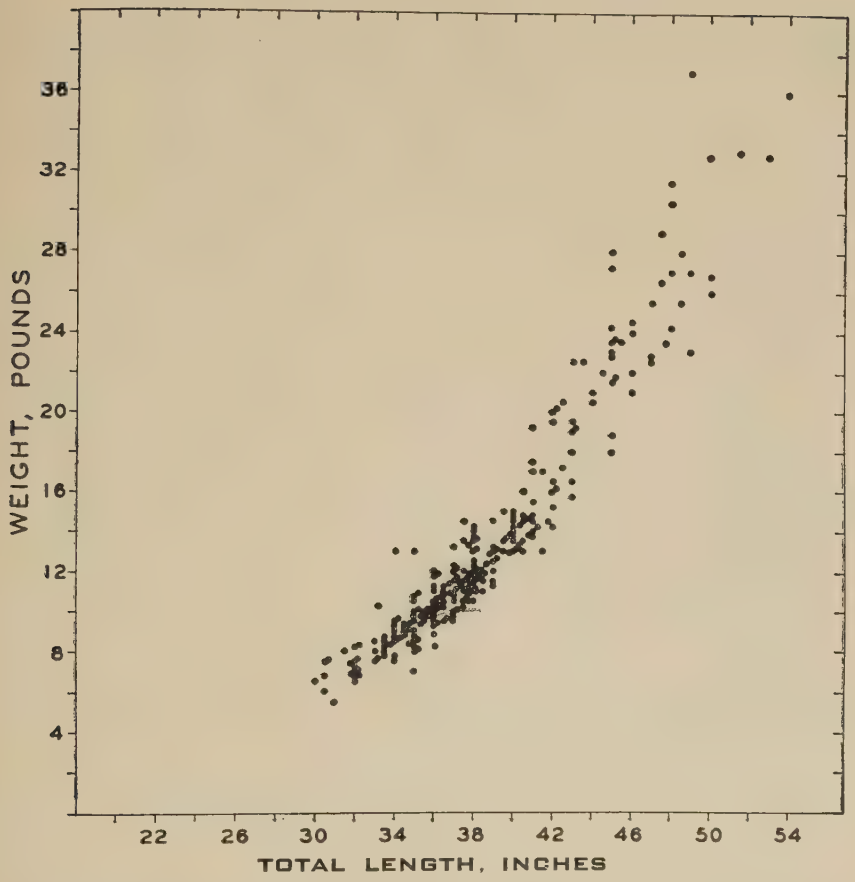

FIGURE 1.—Lengths and weights of individual muskellunge, *Esox m. masquinongy*, from Lake St. Clair, Michigan. Each dot represents one fish.

the actual length-weight relationship cannot be determined from his publication. Upon request, the individual measurements of 184 of the fish that had been used as a basis for Greeley's report plus the data on 15 fish collected in 1942 from Chautauqua Lake, were sent by Dr. Udell B. Stone of the New York Conservation Department. The total lengths of those 199 fish ranged from 12.99 to 51.0 inches and the weights from 0.58 to 33.5 pounds. The data on the 219 fish in the combined series from Chautauqua Lake were taken from fish captured in traps or caught by anglers. Those data were regrouped for the present study into 1-inch classes that included fish from one-half inch below to just less than one-half inch above each inch (Table 2) and a graph made (Fig. 2). Here, again, there was a clear-cut relationship between the lengths and weights

TABLE 2.—*Numbers of Chautauqua Lake muskellunge, grouped at intervals of 1 inch, together with the minimum, average, and maximum weights in pounds for each length group*

[See text concerning sources of data]

Total length (inches)	Number of fish	Weight (pounds)		
		Minimum	Average	Maximum
10.50–11.49	1	.....	0.19	.....
11.50–12.49	..	.....	.....	.....
12.50–13.49	1	.....	0.58	.....
13.50–14.49	1	.....	0.81	.....
14.50–15.49	1	.....	0.57	.....
15.50–16.49	..	.....	.....	.....
16.50–17.49	..	.....	.....	.....
17.50–18.49	2	1.19	1.22	1.25
18.50–19.49	2	1.00	1.07	1.13
19.50–20.49	..	.....	.....	.....
20.50–21.49	1	.....	2.00	.....
21.50–22.49	1	.....	2.56	.....
22.50–23.49	4	2.38	2.81	3.98
23.50–24.49	7	1.94	2.70	3.25
24.50–25.49	5	3.00	3.29	3.50
25.50–26.49	8	3.50	4.06	4.50
26.50–27.49	8	3.64	4.42	5.50
27.50–28.49	13	4.13	4.94	5.75
28.50–29.49	7	4.50	6.05	7.00
29.50–30.49	18	5.75	6.35	8.00
30.50–31.49	15	6.00	7.41	8.75
31.50–32.49	26	7.00	7.86	9.00
32.50–33.49	25	6.25	8.29	10.00
33.50–34.49	23	7.00	9.07	10.59
34.50–35.49	6	8.75	10.25	15.00
35.50–36.49	13	8.25	10.62	13.25
36.50–37.49	5	9.50	10.60	12.00
37.50–38.49	5	11.00	12.28	13.50
38.50–39.49	2	12.00	12.13	12.25
39.50–40.49	1	.....	13.60	.....
40.50–41.49	2	14.75	14.97	15.19
41.50–42.49	1	.....	14.00	.....
42.50–43.49	2	18.00	20.50	28.00
43.50–44.49	5	19.50	21.30	26.00
44.50–45.49	1	.....	21.00	.....
45.50–46.49	..	.....	.....	.....
46.50–47.49	2	28.00	28.25	28.50
47.50–48.49	3	26.00	27.23	29.19
48.50–49.49	..	.....	.....	.....
49.50–50.49	..	.....	.....	.....
50.50–51.49	2	33.50	34.75	36.00

of the fish. Also the weights of individual fish of a given length group differed considerably, and those differences became greater as the lengths of the fish increased.

A comparison of the average weights for fish of the same length group from each of the two lakes indicates that the discrepancies are small even though the members of the population in one lake are sub-specifically different from those in the other (Tables 1 and 2). Furthermore, there is fairly close agreement in the minimum and maximum weights of fish of a given length from both bodies of water. When the data for the average weights of fish from each population are plotted on the same graph (Fig. 3), those similarities are obvious. The length-weight data on the muskellunge from the two lakes apparently complement each other inasmuch as the bulk of the individuals from Chautauqua Lake were 37 inches or less in length whereas those from Lake St. Clair were 32 inches long or longer.

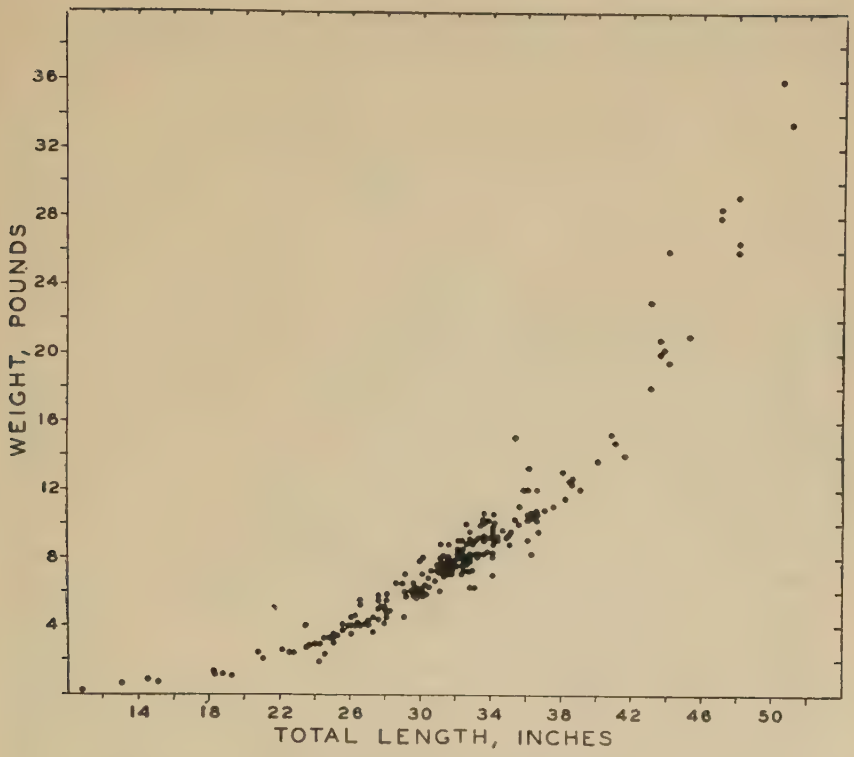

FIGURE 2.—Lengths and weights of individual muskellunge, *Esox m. ohiensis*, from Chautauqua Lake, New York. Each dot represents one fish.

More recently, Williams (1948) listed a total of 250 records of muskellunge taken from 26 localities in Michigan. Those records included 133 from the connecting waters between Lake Huron and Lake Erie (Lake St. Clair, Anchor Bay of Lake St. Clair, Detroit River) and 117 from inland waters. The fish from the connecting waters between Lake Huron and Lake Erie were obviously Great Lakes muskellunge whereas those from some of the inland waters were probably Wisconsin muskellunge (*Esox m. immaculatus*). None of the records reported by Williams were the same as those used in the present study. The length-weight data presented by Williams were based on measurements of 162 specimens. Just which fish furnished the data as a basis for establishing the length-weight relationship was not mentioned but it is obvious that some of them must have come from inland waters and others from the connecting waters of the Great Lakes. Although no table of lengths and weights was given by Williams, a comparison of his graph with that for the present study

indicates that Williams' fish were generally heavier, especially in the greater length groups.

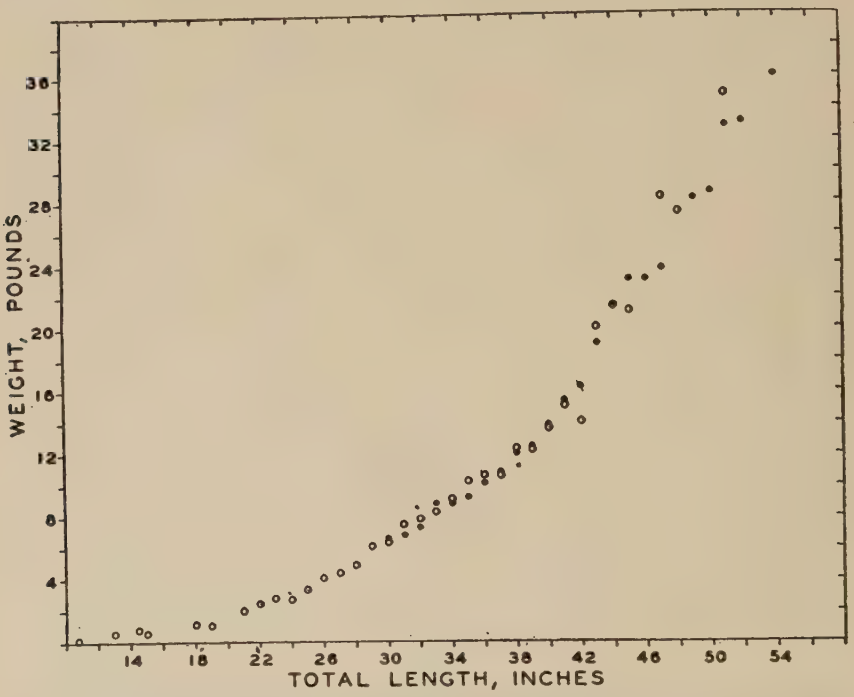

FIGURE 3.—Average lengths and weights of muskellunge from Lake St. Clair, Michigan, *Esox m. masquinongy* (solid dots), and Chautauqua Lake, New York, *Esox m. ohiensis* (open circles).

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WIDER APPLICATION OF THE ELECTRICAL METHOD OF COLLECTING FISH

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Abstract

Limitations of the electrical-shock method of collecting fish, as commonly used, are reviewed. Among these are the facts that the equipment considered necessary is cumbersome and costly; that the method is effective only on quite narrow, clear-water streams; that effectiveness varies greatly with chemical content of soil and water; and that it is dangerous. Equipment and techniques that overcome these limitations to a greater or lesser extent are described. It has been found that less and more simple gear can be used effectively and safely. Methods of handling equipment which eliminate many time-consuming delays have been developed. Equipment and procedures which are fully satisfactory on wider streams and in turbid waters are described. An electric "seine," effective in streams 90 to 100 feet wide, has been developed. By employing special techniques, it can be used quite effectively in wider streams. In turbid water the method is less efficient but quite satisfactory sampling of the fish population can be made.

Preliminary experiments have been made on the amount of electric current needed to stun fish without killing them. Apparently, most species of fish will be stunned but will recover in a few minutes from shock caused by 5 to 6 amperes of alternating current at 110 volts. Larger fish seem to be stunned more readily than those of fingerling size. Experiments on the efficiency of the method have been started. Factors influencing efficiency are believed to be chiefly those related to the recovery of stunned fish. Turbid water, swift current, and rough bottom all seem to decrease efficiency. Experimental evidence to confirm these beliefs is incomplete and inconclusive but it is evident that the method is highly effective in sampling qualitatively areas which otherwise could not be worked.

Introduction

Widespread use of the electric-shock method for making fish-population studies probably dates from the publication of papers by Haskell (1940) and by Haskell and Zilliox (1941). Since that time the method has come into rather common use by fishery research agencies and many improvements have been made on the equipment and techniques as originally described. Articles dealing with these new developments have appeared in none of the journals, however, and it is difficult to obtain information concerning them. This paper deals with the method as it is being used in fishery-census work in Missouri. It is presented in the hope of arousing interest in, and promoting discussion of, the present status of this valuable tool of the fishery biologist.

Common Limitations of Method

The great advantage of the method, that of providing a means of sampling fish populations in waters where bank and bottom conditions make seining impossible, is overbalanced in the minds of many, by its limitations. Some of these are outlined in the following paragraphs.

1. Equipment is cumbersome and costly.—The equipment commonly used consists of a more or less elaborate electrode hookup to be handled in the water, several hundred feet of cable to transmit the current, voltmeters and ammeters to measure the electrical energy, a more or less complicated transformer or rheostat arrangement to control it, and a generator to produce it. The total cost of these items amounts to several hundred dollars and, especially during the past few years, most of them have been very difficult to obtain. Disregarding costs, however, and considering only the difficulties involved in handling the equipment, the following facts are evident. Even the so-called "portable" power plants, if they are of the larger and more powerful types, are extremely heavy and difficult to handle on rough or muddy stream banks. The meters used to measure the electrical energy are delicate instruments requiring careful handling. During operation they and the rheostat require constant attention from a member of the crew. Variations in the resistance within the field makes necessary changes in the rheostat setting to prevent the amperage from rising above the limits lethal to fish. Generally such hookups are protected by fuses which burn out before the established limit is exceeded. This precautionary arrangement may be the cause of many irritating delays. Several hundred feet of electric cable can, also, cause many delays as it becomes lodged or snarled while being dragged along rocky stream beds or brushy banks. Finally, the electrode hookup, although varying greatly in design, will usually require at least two men to operate it, will have wires which frequently become snarled or hung up, and will have numerous connections, that require considerable time to make and release when starting or stopping work and frequently become disconnected during operation, also causing delays.

2. Method is effective only in narrow, shallow, clear streams.—The method has been used most in northern trout brooks and the equipment developed has been designed for use in streams of this type. Little seems to have been done to adapt it to wider, deeper, more turbid waters, even though its use in wide streams or in lakes would be most valuable. The assumption that it would be impossible to recover stunned fish in deep, turbid water has been generally accepted.

3. Effectiveness of method varies greatly with chemical content of water and soil.—This statement undoubtedly was true of the device originally described by Haskell. Improvements described by Haskell and Zilliox did much to overcome the difficulties caused by soil resistance although the device had other limitations which are mentioned.

4. Method is dangerous.—Haskell and Zilliox took great care to point

out the possible danger involved in operating an electric-shocking device. Their warning was so urgent that it may have served to deter some who otherwise would have been interested in trying out the method.

These are a few of the more common limitations of the method as it is ordinarily used. In 1945 it was decided to try out an electric-shocking device (commonly referred to as the electric "seine") as a method of collecting in our fishery-census work in Missouri. During the past two seasons extensive experimentation with the device has been carried on. We have attempted to make the method usable in wider, deeper, and more turbid waters; to reduce the amount of equipment; and to make what is needed in all ways as easy as possible to handle. Several changes in the conventional type of apparatus have been made and several new techniques have been developed. All new developments have been tried out under field conditions and only those which are practical under such conditions have survived. We still have not solved all of our problems. We are still experimenting, but we believe that we have done enough toward overcoming the limitations listed above for our findings to be of interest to others doing similar work.

Description of Equipment

A 110-volt, 60-cycle, alternating-current generator of 500 watts capacity, has been found to provide a satisfactory source of power. Experimentation has shown higher voltages and greater watt capacities to be unnecessary. In the interest of portability it is advisable that the motor be of the air-cooled type. Also, it is advisable to have a plant with casting of light metal alloys rather than cast iron, even though the cost may be somewhat more. A plant equipped with an automatic cut-off which prevents overloading the motor when the rated capacity is exceeded, makes fuses unnecessary and is a distinct advantage. Such plants, weighing less than 150 pounds and equipped with carrying handles, are now available.

The electrode hookup (Fig. 1) used is simple, easily constructed, and easy to operate. Eight "floating grids," connected to one line from the power plant, form one group of electrodes. The floating grids are 2-inch by 3-inch pieces of white pine 3-feet long, covered on three sides with ½-inch-mesh hardware cloth. The wire connecting them is interlaced with the hardware cloth for several inches at each end and is held in place with staples. These grids are arranged in line 10 feet apart from center to center. Connected to the other line from the power plant are seven "drag wires"—7-foot lengths of flexible, uninsulated wire cable weighted at the outer end with lead seine weights to keep them on the bottom. The power line with these drag wires attached is arranged so that the wires hang suspended midway between each pair of floating grids. At each end of the electrode hookup is a "probe pole", a light wooden pole 7 feet long, the lower 2 feet of which is covered with metal, preferably copper. This pole is connected by means of a 10-foot length of insulated wire to the power line to which the drag wires are attached. These, with the drag wires,

form the opposite group of electrodes. The whole apparatus is simply a number of resistances connected in parallel, the water between the various pairs of electrodes forming the resistance. The two power wires are fastened together with friction tape at intervals so that the floating grids keep both near the surface. The size of the floating grid is just sufficient to keep the wires afloat, thus helping to keep the bulk of the entire device at a minimum. All connections are permanent except that of the power lines to the generator. This arrangement eliminates delays in starting and stopping work and during operation. Wire for the power lines should be flexible, insulated, copper cable, size No. 10 or No. 12. Good quality electrical cable of this type is difficult to obtain at the present time, yet if a better quality of cable is used, less trouble will be experienced from breaks and short circuits. We have employed two-wire, No. 18, rubber covered cable

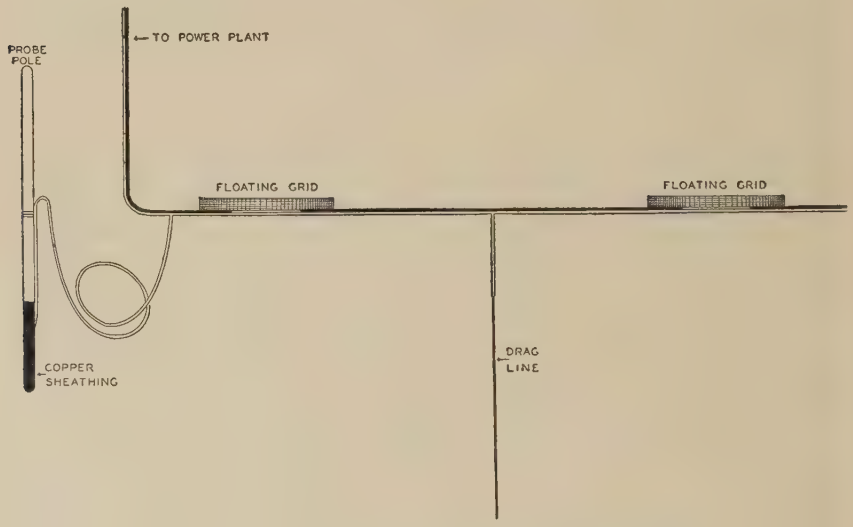

FIGURE 1.—Diagram of portion of electrode hookup.

obtained from army surplus stores, the two wires being used as one. The quality of this cable is good and its cost is comparatively low.

Experience has shown that meters to measure the current and a transformer or rheostat to control it are not needed after the potentials of the device have been established. With a 110-volt, 500-watt power plant equipped with an automatic cut-off, little more than 5 amperes of current ever goes through the lines. This amount is sufficient to stun most fish but not enough to cause serious injury. They recover in a few minutes

when removed from the electrical field. A long transmission line is unnecessary if the power plant is placed in a boat and floated behind the shocking device during operation. With this arrangement a line 50 feet or less in length may be used and delays from snarls, etc., are practically eliminated.

Procedure

Two men are required to operate the electrode hookup in the water (Fig. 2). A length of light rope attached to the outermost floating grid is tied around the waist of each operator, leaving his hands free to manipulate the probe pole and a dip net for picking up stunned fish. One or more additional men devote their entire attention to the recovery of fish. One man handles the boat and power plant and assists in the recovery of fish. Equipment for storing fish, etc., can be carried in the boat.

Figure 2.—The electric seine in operation.

Ordinarily, a stream section is worked by starting at the upstream end and working downstream. This procedure is followed for several reasons: the natural tendency of fish is to swim upstream, sediment stirred up by the operations in carried on by the current, and the equipment is more easily handled. With such a device, streams up to 100 feet wide can be covered thoroughly in one trip. On narrower streams the device is simply

allowed to bag as much as it will, the only effect being to put more of the total water area within the electrical field. Wider streams can be worked by following the shoreline with one end of the apparatus while the other end is extended full length, and the whole device is kept at an acute angle with the bank. By moving along both margins in this way a fairly thorough sampling of the fish population can be obtained. If the middle portion of the stream is too deep for wading, the outside man may be carried in the boat, although this technique as a rule is not especially effective, if for no other reason than that the stunned fish are difficult to recover in water so deep.

This equipment and these procedures go far toward overcoming the first two limitations mentioned. The third, namely that the effectiveness of the method varies with the chemical content of the water and soil, has not proven to be true with the apparatus described. Soil resistance is unimportant since with this device probably very little of the electric current goes through the soil. Our records show that the apparatus has been used with apparently equal success in waters of which the calcium carbonate content varied from 75 p.p.m. to 177 p.p.m. It seems probable that most natural waters, at least running water in streams, contain enough dissolved minerals to transmit electric current readily. The final limitation, that the method is dangerous, is best met by following the admonition of Haskell and Zilliox: "A major precaution for the safety of the crew is proper supervision." All of our crew members are required to wear waders and electrician's rubber gloves at any time that the power plant is in operation. So far, the greatest casualties have been minor shocks occasioned by falling or overtopping waders while within the field.

Efficiency of Method

Haskell and Zilliox described a number of tests of the efficiency of the electric-shock method. Their work was all conducted on small trout streams. They concluded that for trout more than 4 inches long recovery was 80-percent or greater and that for fish of this size width of stream, depth of water, type of section, and type of bottom do not have an important effect upon recovery. They found the recovery of fingerlings to be highly variable. Schuck (1946) also described a study of the efficiency of the method in collecting trout. His findings showed that in the areas studied the size of the fish was the most important factor affecting efficiency. His recovery figures range from 95 percent for age-groups III to V (21.4 to 41.2 centimeters) to 50 percent for age-group 0 (5.2 to 10.5 centimeters). He stated: "The larger trout were captured more efficiently, possibly because they were more conspicuous after being stunned."

Our experience, in general, bears out these findings regarding efficiency in recovery of fish of various sizes, although it is apparent that stronger shock is necessary to stun small fish. With the electrode hookup as described above, there is ordinarily no place where a fish passing through the field can be more than about 4 feet from an electrode. At this distance

most fish of moderate or large size are stunned but small fish are frequently observed to swim through the field unaffected. They must come to within 1 or 2 feet of an electrode to be stunned.

We have determined further that the physical features of the stream section have a great effect upon the efficiency of the method. Schuck's study, in which the percentages of recovery were so high, was made upon four blocked-off sections of a New York trout stream. The stream area as a whole averaged 24.3 feet in width, 14.6 inches in depth, had a flow of 10 to 15 cubic feet per second, had a bottom of sand or sand, rubble, and boulders, and can be presumed to have been clear. His results are, no doubt, accurate for such a stream but they should not be accepted as applicable to streams with different physical characteristics. The physical factors which we observed to influence efficiency most are, in order of importance: turbidity, depth, type of bottom, and velocity of current.

That turbidity should be a factor in efficiency is obvious, since the more turbid the water the more difficult it is to see and recover stunned fish. However, surprisingly large collections of fish, particularly large specimens of redhorse (*Moxostoma*), carpsucker (*Carpiodes*), buffalo (*Ictiobus*), and carp (*Cyprinus*), have been made from highly turbid waters. It is not intended to intimate that only these fish are affected in such waters; many other species also are taken. The fish named are likely to be numerous in turbid waters, however, and the large individuals are most conspicuous and thus most likely to be recovered. So far no experiments to show the correlation between turbidity of the water and the proportion of the fish population recovered have been undertaken. The chief effects of depth are to limit the movements of the men assigned to recover stunned fish and to make the fish more difficult to see. When one is standing waist deep or deeper in a stream it is difficult to see into the water at any distance even though it may be quite clear. In such situations, a man standing in the boat may be helpful in locating stunned fish. As in turbid waters and for the same reason, disproportionately large numbers of large fish are likely to be recovered from deep waters. High current velocity affects efficiency chiefly by carrying stunned fish out of the electric field before they can be recovered. If the device is used as described above, however, fish swept out of the riffle areas can be expected to be taken in the quiet water below so that the final effect is minimized. No experiments have been made to ascertain the effect of this factor.

The effect of bottom type is not so obvious as that of the factors described above but it is considered to be of great enough importance to receive special consideration. First of all, bottom type is closely allied with turbidity. The water over a mud or clay bottom may be relatively clear when undisturbed but roils up immediately when any agitation occurs. Fine sand exhibits the same characteristic to a lesser degree. Gravel or rubble bottoms may contain considerable mud or may be covered with partially decomposed algae, etc., which, when disturbed, roils the water. These are the more obvious factors connected with bottom type.

Less obvious but of great importance in the collection of fish with an electric-shocking device is the effect of rocks, submerged logs, undercut trees or stumps, piles of drift, and like forms of cover for fish. It is in areas where such cover is abundant that the major portion of the fish population of a stream is likely to be found. Furthermore, it is these objects that make conventional seining impossible and that furnish the best argument for the use of the electric seine. Even with the shocking device, however, it is difficult to recover a very large proportion of the fish population unless great care is taken. Fish, when affected by the electric current, usually take for cover in their last convulsive effort before they are completely stunned. It is a common experience of our crew members to see an affected fish disappear under a rock. If the rock can be moved, several stunned fish frequently are found beneath it. Submerged logs offer much the same sort of refuge. Deeply undercut banks and, especially, undercut trees or stumps with roots projecting into the water, are particularly difficult to work. Fish stunned in such situations do not come to the surface and are likely to be overlooked altogether. When experiments to test the efficiency of the electric shock method were set up it was decided that as great a variety of bottom types as possible should be included in an attempt to evaluate this factor. Of course, there was necessarily considerable variation in the other physical factors so that the results are by no means conclusive.

Experiments to test the efficiency of the shock method were started during 1947. They are not yet complete and in two of the three studies made it appears that factors other than the efficiency of the seine may have interfered to cause unexpectedly low recovery figures. The experiments all follow the same general pattern.

A section of stream was blocked off by means of ¼-inch-mesh seines placed at each end. The blocked-off area was stocked with fish of as great a variety of species and size as could be obtained. Each planted fish was weighed, measured, and marked, either with a tag or by having a fin clipped. It is recognized, of course, that fish so planted might be more easily recovered than undisturbed fish native to the area. The fish were given a short time to become acclimated, then the section was covered as thoroughly as possible with the shocking device. The number of times it was gone over depended upon such factors as the time required for the resulting turbidity to subside or the length of time it was practical to maintain the blocking seines. In tabulating the results, fish of the various species were divided arbitrarily into size groups by total length. For sunfish the size range in each group was 1 inch; for black bass, redhorse, and fish of similar size, 2 inches; for carp, 4 inches.

The first experiment was conducted on Swan Creek, a tributary of the Gasconade River, in Osage County. The blocked-off area was about 200 feet long, averaged about 60 feet wide, and ranged up to 5 feet deep. Current velocity was slight but sufficient to bag the blocking seines somewhat. It was estimated that 65 percent of the bottom area furnished good

cover for fish in the form of undercut banks—some with trees or stumps—several fallen trees (partially submerged), and two accumulations of drift material. The bottom was about half gravel, with a covering of ooze, and half mud or clay. For this reason turbidity became high as the work progressed. The area was gone over three times, once the day the fish were planted and twice the succeeding day. Turbidity, which was measured by the U. S. Geological Survey platinum-wire method before each seining, varied from 9 p.p.m. to 11 p.p.m. Results of the experiment are shown in Table 1. Twenty-two fish, including largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), longear sunfish (*Lepomis megalotis*), green sunfish (*Lepomis cyanellus*), rock bass (*Ambloplites rupestris*), redhorse (*Moxostoma* sp.), hogsucker (*Hypentelium nigricans*), and carp (*Cyprinus carpio*), were planted. Of these, nine, or 40.9 percent, were recovered. Individuals of all species planted except largemouth bass and green sunfish were retaken. Only one each of these two species had been included in the original planting. A total of 32 fish, including, in addition to the above species, channel catfish (*Ictalurus lacustris*), buffalo (*Ictiobus* sp.), bluegill (*Lepomis macrochirus*), gizzard shad (*Dorosoma cepedianum*), and shortnose gar (*Lepisosteus platostomus*) were taken in the three sweeps.

TABLE 1.—*Species, number, size range, and average length of planted fish and number recovered in Swan Creek experiment*

Species	Number planted	Size range (inches)	Average length (inches)	Number recovered
Largemouth bass	1	10.0–11.9	11.25	0
Smallmouth bass	1	4.0– 5.9	4.67	0
	1	6.0– 7.9	6.37	1
Longear sunfish	3	3.0– 3.9	3.42	1
	2	4.0– 4.9	4.31	1
Green sunfish	1	3.0– 3.9	3.25	0
Rock bass	4	6.0– 6.9	6.62	1
Redhorse	2	8.0– 9.9	9.19	2
	1	10.0–11.9	10.37	1
	1	12.0–13.9	12.50	0
Hogsucker	1	6.0– 7.9	7.12	1
	2	8.0– 9.9	8.69	0
Carp	2	6.0– 9.9	7.69	1
Totals	22	.....	.....	9

The second experiment was conducted in the headwaters of the Gasconade River in Wright County. The section blocked off was 420 feet long, averaged 35.8 feet in width, and 11.1 inches in depth. The greatest depth was 3.5 feet. The bottom was about 75 percent gravel with a covering of algal slime and the remainder mud, clay, or fine sand. About one-

third of the bottom area furnished good cover for fish. This shelter consisted of two clumps of undercut trees along one bank, and several submerged logs, stumps, etc. Volume of flow was estimated at 10 cubic feet per second. Turbidity was not determined because of the shallowness of the water but the bottom was plainly visible in all parts of the section before operations were started. The area was gone over twice with the shocking device on the day after the fish were planted. Results are given in Table 2. Fish planted included 1 smallmouth bass, 1 largemouth bass, 27 longear sunfish, 14 bluegills, 10 green sunfish, 9 redhorse, and 1 carp to make a total of 63. Of these, 4 longear sunfish, 5 green sunfish, and 1 carp—a total of 10 or 15.9 percent—were recovered. This figure probably

TABLE 2.—*Species, number, size range, and average length of planted fish and number recovered in Upper Gasconade River experiment*

Species	Number planted	Size range (inches)	Average length (inches)	Number recovered
Largemouth bass	1	4.0– 5.9	4.0	0
Smallmouth bass	1	6.0– 7.9	6.25	0
Bluegill	[1]5	3.0– 3.9	3.45	0
	[1]5	4.0– 4.9	4.47	0
	[1]4	5.0– 5.9	5.37	0
Longear sunfish	10	3.0– 3.9	3.26	0
	16	4.0– 4.9	4.47	3
	1	5.0– 5.9	5.37	1
Green sunfish	5	3.0– 3.9	3.47	1
	3	4.0– 4.9	4.50	3
	1	5.0– 5.9	5.50	1
	1	6.0– 6.9	6.50	0
Redhorse	[1]1	6.0– 7.9	6.50	0
	[1]7	8.0– 9.9	9.37	0
	[1]1	10.0–11.9	10.37	0
Carp	1	22.0–25.9	23.50	1
Totals	63	.....	.....	10

[1] Survival improbable; survival of others questionable.

does not represent the true efficiency of the method, however. The remains of three planted fish, two bluegills and a redhorse, were found in the lower blocking seine. An abundance of heron tracks within the blocked-off area would indicate that more of the planted fish may have been killed. A total of 182 fish of measurable size, that is, a half-ounce or more in weight, were taken from the area in the two sweeps. Included were 4 smallmouth bass, 3 largemouth bass, 8 rock bass, 14 bluegills, 61 green sunfish, 84 longear sunfish, 1 redhorse, 5 hogsuckers, 1 carp, and 1 river chub.

The third experiment was carried on in the headwaters of the Meramec River in Dent County. The experimental area was located at the lower end of a long pool. It was 190 feet long, and 80 feet wide at the upper

end, tapering gradually to 32 feet at the lower end. The average depth was 1.7 feet with a maximum of 4 feet near the upper blocking seine. The bottom was gravel and rubble with numerous boulders, all covered with algal slime. The rocks and boulders provided the only cover. Turbidity was 7 p.p.m. before work was started. Volume of flow was 16.6 cubic feet per second. Fish planted consisted of 3 smallmouth bass, 11 longear sunfish, 2 green sunfish, 2 rock bass, 20 redhorse, 3 hogsuckers, and 1 yellow bullhead (*Ameiurus natalis*)—a total of 42. The area was covered twice with the electric seine on the day the fish were planted. Results are given in Table 3. Of the planted fish, 11 or 25.2 percent were recovered. The fish recaptured were 1 smallmouth bass, 3 longear sunfish, 1 green sunfish, 1 rock bass, 4 redhorse, and 1 hogsucker. These recovery figures seem small—especially for the redhorse which were the largest and most numerous of the planted fish. It is possible that some of them may have been missed in the deeper water where it was impossible to see the bottom

TABLE 3.—*Species, number, size range, and average length of planted fish and number recovered in Upper Meramec River experiment*

Species	Number planted	Size range (inches)	Average length (inches)	Number recovered
Smallmouth bass	1	4.0– 5.9	5.25	0
	2	6.0– 7.9	6.81	1
Longear sunfish	3	3.0– 3.9	3.38	0
	5	4.0– 4.9	4.35	2
	2	5.0– 5.9	5.25	0
	1	6.0– 6.9	6.50	1
Green sunfish	2	5.0– 5.9	5.44	1
Rock bass	1	5.0– 5.9	5.75	0
	1	7.0– 7.9	7.12	1
Redhorse	1	6.0– 7.9	6.75	1
	5	8.0– 9.9	9.68	1
	11	10.0–11.9	11.15	2
	3	12.0–13.9	12.46	0
Hogsucker	3	12.0–13.9	12.33	1
Yellow bullhead	1	8.0– 8.9	8.50	0
Totals	42	.....	.....	11

or that some may have escaped under the blocking seines. The low recovery of the smaller fishes explained by the presence of many boulders and large rocks under which they were hidden.

Although this series of experiments is incomplete and not conclusive, it would seem to be evident that the efficiency of the electric-seine method, like that of any other method of collecting fish, varies with the physical characteristics of the area being studied. Each stream section presents an individual problem. Some additional facts are also evident. In most

places the percentage of large fish recovered was greater than that of the smaller individuals of the same species. This fact can be explained in two ways: small fish are more likely to be overlooked, and small fish require a greater amount of electric current to stun them. It is evident also that most species of fish are affected. Our records for the past two seasons show that in addition to the species used in the experiments practically all fishes native to Missouri waters have been taken by the electric-shock method. Lampreys (*Ichthyomyzon* spp.), paddlefish (*Poloydon spathula*), and catfishes of all kind including madtoms (*Schilbeodes* spp.), bullheads (*Ameiurus* spp.), and flathead catfish (*Pilodictis olivaris*), as well as channel catfish have all been taken. Eels (*Anguilla bostoniensis*) are highly susceptible although they are difficult to recover. Gar (*Lepisosteus* spp.) are taken easily and at times in alarming numbers. Finally, it should be evident from these data that large numbers of fish can be collected by this method from areas in which it would otherwise be impossible to sample the fish population. To illustrate this point further let me review the species taken in a section of the Meramec River on May 31, 1947. The area was 765 feet long, averaged 87.6 feet in width, and 2.4 feet in depth, with a maximum depth of 5.75 feet. Cover, chiefly in the form of boulders and submerged logs, was abundant and prevented working the area by any other method. Included in the take were 20 smallmouth bass, 6 rock bass, 48 longear sunfish, 24 green sunfish, 3 bluegills, 28 redhorse, 5 hogsuckers, 2 carp, 1 chub, and 1 bullhead, a total of 138 fish. These were taken in a single sweep over the area, in a little less than 2 hours. We cannot say with certainty what proportion of the total fish population of the area this catch represents but certainly it is a good qualitative sample.

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SOME HARMFUL EFFECTS OF THE ELECTRIC SHOCKER ON LARGE RAINBOW TROUT

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Abstract

The use of the electric shocker in the salvage of rainbow trout (*Salmo gairdnerii*) from an irrigation canal is described. An account is given also of physiological effects observed during shocking and the morphological effects determined by dissection. In order to determine the effects of shocking, the trout were transferred to a holding pond at a state fish hatchery and observed for 2 to 5 days before being released.

Dissection of some of these specimens disclosed fractured vertebrae, ruptured arteries and veins, hemorrhaging, death of tissues (secondary), curvature of the spine, and extreme dilation of blood vessels in various parts of the body, including the brain.

The possibilities of the application of the shocker to other phases of fishery management are discussed.

Introduction

Since the inception of its use, the electric shocker in one or another of its modifications, has been employed largely for the collection of fish. Haskell (1940a) described the value of the shocker for stream-census work. Haskell and Zilliox (1941) reported on its use in the removal of smallmouth black bass from trout waters and in stream-population studies. Shetter (1947) described the latter use of the shocker in Michigan streams. As far as can be determined, all of these applications of the shocker were made on smaller fish; the largest recorded were only 11.5 inches long.

A further application of the shocker was made by members of the Idaho Fish and Game Department in October 1947 in a determination of the actual loss of game fish in the Richfield Canal when its flow of water was shut off. Seining was impractical because of the lava-rock bottom and the dense beds of aquatic vegetation. It was thought that with the shocker it might be possible to recover a greater percentage of fish than by any other method.

Materials and Methods

A portable generator of 110-volt, 60-cycle alternating current, with a maximum output of 495 watts, and powered with a gasoline engine was the source of electrical energy. It was fitted with a field rheostat for the control of the voltage. Rubber-insulated wires carried the electricity to two rectangular electrodes which were modifications of those described by

Shetter (1947). The frame-work of the electrodes was constructed of ½-inch copper tubing to which vertical heavy copper wires were soldered at 4-inch intervals. The electrode was fitted to a 5-foot hardwood handle. The generator and other equipment were transported along the canal bank in a pickup truck. A 15-foot pole attached to the truck in an upright position carried the wires over obstructions, such as willows. Two men operated the electrodes in the canal. The driver of the truck managed the operation of the generator and its rheostat. From one to three men collected the stunned fish in dip nets and carried them to a tank truck which followed the pickup truck along the bank. By use of this method the crew of men could cover a distance of 3 to 4 miles a day. The rescued rainbow trout were transported to the nearby Hayspur State Fish Hatchery and held under observation for 2 to 5 days. Specimens that were to be kept for dissection were preserved in 10-percent formalin.

A voltage just high enough to stun the fish momentarily (80-90 volts in this particular water) was used. The electrical field was effective within a radius of 10 feet and to a depth of 5 feet. The water in the canal was alkaline, with a pH of 7.5. Its temperature ranged from 58 to 70° F.

Physiological Effects

The reactions of the rainbow trout to contact with the electrical field between the electrodes were varied. Increased respiratory action was evident in all fish. Paralysis of the swimming musculature was typical and ranged from complete paralysis to paralysis of the side nearer the electrode so that the fish swam in an arc around the source of current. Total paralysis caused the fish to float on their sides momentarily, after which they slowly sank to the bottom.

A number of fish hemorrhaged from the gills or vent, or both. Others showed dilated and hemorrhaged blood vessels in the skin near the vent. Several were observed with the intestine protruding from the vent.

Physical contact with the electrode caused the appearance of dark vertical bars on that area of the fish which touched the electrode.

Five hundred three of the shocked, rescued rainbow trout, averaging 3.7 pounds, were transferred to a holding pond and observed before being released. Of these, 131 died as a result of shocking or subsequent handling. Paralysis of swimming muscles persisted in some fish for several days. This loss, or partial loss, of locomotion would indicate an injury to the nervous system. The dark, vertical bars remained in evidence. Dead or dying tissues in the caudal peduncle and caudal fin appeared on several fish which fact would indicate loss or impairment of circulation to this region. Several fish lost their sense of balance.

Injuries Disclosed by Autopsy

Ten of the rainbow trout that exhibited representative symptoms of injury were selected and preserved for later study. Because of the lack of both time and facilities, a detailed study could not be made. The 10 fish

dissected, however, comprised 8.3 percent of the total observed loss; it might be assumed therefore, that each type of injury determined by dissection would represent, roughly, 8 percent of the occurrence of that injury in the deceased fish, and 2 percent in the entire lot.

Injuries attributable to the use of the shocker were varied. One 5-pound rainbow trout had a fractured sixth caudal vertebra. As a result of this fracture the haemal artery and vein had ruptured in the seventh caudal vertebra. The breakdown of circulation of blood at this point caused the death of the entire body posterior to the injury, including muscles and skin. Blood clots and hemorrhaging were evident throughout the caudal peduncle, particularly in the region adjacent to the fracture. This fish suffered total paralysis of the swimming musculature before its death.

A 1.5-pound specimen had three fractured vertebrae, the 11th, 29th, and 30th abdominals. Curvature of the spine appeared through the abdominal vertebrae 18-22, and the ligamentous connections between ribs and parapophyses in this region were broken. This fish also had blood clots in the afferent branchial arteries and had hemorrhaged through the membranes of the gill filaments.

A rainbow trout weighing 1.8 pounds had its 30th and 31st abdominal vertebrae fractured, and one of 1.7 pounds showed spinal curvature (ligamentous fracture) through the abdominal vertebrae 27-31. The fluid in the semi-circular canals of the latter specimen was bloody. This fish had an impaired sense of balance before it was killed.

One specimen which exhibited paralysis of one side before death had a fractured 19th abdominal vertebra. A 3-pound fish had a fractured 29th abdominal vertebra and curvature of the spine through this section. Twelve dorsal arteries anterior to this fracture were ruptured.

In addition to the injuries just described, 6 of the 10 rainbow trout had suffered injury in the region of the brain as evidenced by dilated blood vessels or blood clots. These injuries, however, were superficial in comparison to the other damage, and hence could have been secondary effects of the reaction of the fish to the electric current caused, for example, by collision with rocks or other obstructions.

Conclusions

The electric shocker is an efficient instrument in fishery-management work but further experimentation to determine its injurious effects upon fish is needed before it is employed too widely. The violently spasmodic muscular reaction of the fish to contact with electric current causes injuries which can lead to eventual death, or to a permanent impairment of locomotion or of sense organs.

The shocker has been employed for fish-population studies in streams, for fish-rescue work in canals, streams, or small ponds, and as an anesthesia in tagging fish (Haskell, 1940b). In these applications, however, it should be used with care. As a means of collecting fish specimens or of

eradicating undesirable species from streams or portions of lakes the shocker is practical as well as efficient.

The rapid advancements being made in the field of electronics possibly will lead to the development of a precision instrument which will have many sound, safe applications in the field of fishery management.

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THE FERTILITY OF BROWN TROUT EGGS AT THE JONKERSHOEK INLAND FISH HATCHERY

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Abstract

This paper covers the findings of 10 years of research on the problem of the low fertility of brown trout eggs (*Salmo trutta*) at the Jonkershoek Inland Fish Hatchery, Stellenbosch. As a background to the problem a brief résumé is given of the acclimatization of trout in South Africa with which the development of the Jonkershoek Hatchery has been closely associated.

The investigation was commenced on the artificial factors such as stripping, hatching-house technique and diet. Thereafter both the male and female stock fish were thoroughly examined and finally as complete a record as possible was obtained of climatic conditions at Jonkershoek as compared with other trout waters. The more important findings of this investigation follow. *1.* The fertility of the ova was raised by a modification in stripping technique. *2.* There is a period of optimum fertility at which stage the eggs should be stripped. Eggs stripped prior to this period may be infertile due to underripeness, whereas those stripped after may be overripe. *3.* The maximum mortality in any one batch of eggs can be expected on the ninth day after impregnation. *4.* The genital system of the male is normal and the effective life of the milt in water does not exceed 40 seconds. *5.* The genital system of the female appears to be normal. *6.* By improving the diet and by regular feeding the stock fish have gained in condition, the yield of ova has been raised and the eggs made easier to strip. Good feeding of the cocks is as important as that of the hens. *7.* While ecological factors such as streamflow and temperature are by no means optimum, none of the factors investigated presents a definite obstacle to the culture of trout.

Although an improvement in the fertility of the eggs and general condition of the breeders has been brought about, the problem of the low fertility of the brown trout ova at this hatchery has by no means been solved. While the mean is just over 80 percent, the fertilities of individual batches vary. Not infrequently fertilities of 98 percent have been recorded, which leads one to hope that it will become possible to raise the general standard to this level.

Introduction

This paper covers the findings of 10 years of research on the problem of the low fertility of brown trout ova (*Salmo trutta*) at the Jonkershoek Inland Fish Hatchery, Stellenbosch. A certain amount of the material contained herein has been presented in earlier publications. It has been purposely included in this paper, however, with the object of presenting the problem as a whole and in the correct perspective to the numerous factors involved.

As a background to the problem it was considered desirable to give a brief résumé of the acclimatization of trout in South Africa, with which the development of the Jonkershoek Hatchery has been closely associated. The following historical account has been condensed from Report No. 1 of the Inland Fisheries Department to which recourse may be taken for full details.

Only occasional mention of the rainbow trout (*Salmo gairdnerii*) is made in this paper, since on the whole little difficulty is experienced in its culture at the Jonkershoek Hatchery.

Historical Background

The dearth of sporting and edible fish in the streams of the southern and eastern coastal areas of the Cape led to attempts at stocking these waters with suitable exotic species. In 1876 Mr. Campbell Johnston transported a consignment of salmon and trout eggs in the ice house of the S. S. Windsor Castle. Some were landed at Cape Town and the remainder taken on to Natal, but none survived the voyage.

In 1884 Mr. Lachlan MacLean imported 20,000 brown trout ova which were placed in hatching boxes, supplied with water from the Upper Breede River near Wolseley, Cape Province. It is recorded that 17,000 eggs were hatched, but that nearly all the fry were poisoned by the action of the soft water on the zinc lining of the hatching troughs. The chief difficulty in the handling of trout ova imported from Britain is that they arrive in the Cape summer when most waters are too warm for the purpose.

In 1890 the Cape Government agreed to provide funds for further attempts to be made on a larger scale. In 1892 Mr. E. Latour, the pisciculturist chosen for the work, arrived in Cape Town with boxes of brown trout ova supplied by Thos. Andrews of Guildford, Surrey. Sixty thousand of the ova were placed in a mountain stream above Stellenbosch. The balance, hatched in Newlands, gave some 60,000 fry which were divided between a pond at Newlands, some vleis on the Cape Flats and the Lourens River, Somerset West. The fry resulting from the importation of 80,000 additional eggs were portioned out between the Breede and Berg Rivers.

As the pond accommodation at Newlands was too limited, Mr. F. G. Watermeyer leased to the Cape Government a portion of his farm "Jonkershoek" on the upper reaches of the Eerste River in the mountain valley above Stellenbosch. A small tributary of the Eerste River, the Bosboukloof stream, was diverted to feed a hatching house and some ponds terraced on the hill slope. In 1894 100 large trout and 5,000 yearlings were transferred from Newlands to the ponds at the new hatchery.

Mr. John L. Scott who had been associated with Armisteads Solway Fisheries, Dumfries, Scotland, was appointed as Curator of the Jonkershoek Hatchery and the balance of the trout at Newlands were either removed to Jonkershoek or released in various rivers. By the end of 1894, Scott

recorded that he had a breeding stock of about 400 brown trout. The first spawning of brown trout at Jonkershoek commenced at about the beginning of June 1895 and continued until September, which is much later than the present-day season, the latter extending from the middle of May to early August. Scott found that some of the brown trout "did not give up their ova at the right time" and commented that he had not seen similar cases in Scotland. He stripped 15,000 ova from which he hatched 13,000 fry and reared 5,000. According to his observations, the high water temperature in February (30°C.) did not have any appreciable ill effects on the trout, which fact led him to the conclusion that trout could withstand higher water temperatures at the Cape than in Europe because the water at Jonkershoek rarely went below 10°C. in winter. By the winter of 1898 the majority of Scott's brown trout spawners had been produced from colonial ova and he considered that these fish spawned more effectively than their parents which had been reared from imported ova. He stripped 85,000 ova from 83 brown trout hens. It was found, however, that large, high-conditioned trout gave a poor yield of ova and were liable to congestion of the ovaries. Scott attributed the low fertility of brown trout ova in 1902 (approximately 50-percent fertility) to the poor quality of the food. He recorded that the high water temperatures of 12°C. in the 1904 season had no ill effects upon the ova but caused them to develop more rapidly.

In Scott's last report in 1906 he claimed to have stripped 171,000 ova with an average fertility of 95 percent. The poor condition of the ponds and stock fish when his successor took over as well as subsequent experience would cast some doubt on this claim of exceptionally high fertility.

Mr. F. G. Chaplin came from the Pirie Trout Hatchery, Kingwilliamstown, and assumed duty as Curator of the Jonkershoek Hatchery in 1907. At that time there were 19 ponds, the majority of which were badly silted and overgrown. By 1909 Chaplin had constructed eight new ponds and had effected considerable improvements in the way of cleaning and remaking existing ponds, laying out pond surroundings, making concrete lining furrows, constructing new water controls, and planting aquatic vegetation.

The distribution of eyed ova was greatly increased in 1910 when 172,000 were produced. With the help of only one native laborer, Chaplin distributed 179,000 ova in 1912 and 123,000 in 1913. In 1915, as a result of a meat shortage owing to war conditions, Chaplin, like his predecessor Scott in 1900 and 1901, suffered a setback in ova production. By 1916 there was some improvement and ova production again rose above 100,000. From this stage onwards, however, the Jonkershoek Hatchery did not specialize in the production of trout ova to the same extent as the Pirie Hatchery, Kingwilliamstown, and consequently the output of ova steadily declined to the level of approximately 50,000 per annum. Although the fertility of the rainbow trout was satisfactory, that of the brown trout ova had always been erratic, with a mean of approximately 50 percent.

The output of ova from the Jonkershoek Hatchery in recent years is indicated in Table 1.

The total output of 1946 falls little short of the annual requirements of Southern Africa at present, and by devoting more pond space to trout, I have no doubt that the deficit could be met. It must be admitted that temperatures rise alarmingly and streamflow drops away to dangerous limits in some years and it is a possibility that in an exceptionally dry year

TABLE 1.—*The production of brown and rainbow trout ova at the Jonkershoek Hatchery from 1940 to 1946*

Species of trout	Year						
	1940	1941	1942	1943	1944	1945	1946
Brown.....	13,000	30,000	40,000	56,000	66,000	60,000	116,000
Rainbow....	18,000	21,000	38,000	76,000	138,000	230,000	250,000
Total.....	31,000	51,000	78,000	132,000	204,000	290,000	366,000

conditions might become so bad that large-scale mortalities would result. Such an eventuality would have to be faced anywhere in South Africa, however. A scheme is at present under consideration for "boosting" the water supply by pumping back, and when this is in operation the water supply will be reasonably reliable.

Today, more than ever before, Jonkershoek is supplying the ova requirements of Southern Africa. The output of the Pirie, the only other trout hatchery in South Africa, has fallen away from 250,000 to 60,000. This institution has, however, recently been acquired by the Cape Provincial Administration which should now be in a position to meet all reasonable demands. It is estimated that the output of trout ova from the two institutions could be increased to 500,000 if necessary.

FERTILITY INVESTIGATIONS

The problem of the low fertility of brown trout eggs at the Jonkershoek Hatchery is not only of scientific interest but of direct economic importance to the Cape Provincial Administration. Apart from the labor involved in removing dead eggs from the hatching grilles each day, approximately half the output of ova from the hatchery was being lost through initial infertility. For these reasons it was the first problem to be investigated when a research officer was appointed in 1937.

It was appreciated at the outset of the investigation that this infertility might be due to any one of a host of factors or combinations thereof, ranging from unsuitability of cultural technique to an unfavorable climate. It was therefore decided to investigate as many single factors as possible, and on the basis thereof to introduce improvements with the object of effecting a gradual improvement in the quality and output of ova. Investigation was commenced on the artificial factors such as stripping, hatching-house technique, and diet. Thereafter both the male and female stock fish (cocks and hens) were thoroughly examined and finally as complete a

record as possible was obtained of climatic conditions at Jonkershoek as compared with other trout waters.

Stripping Technique.—The stripping technique in use prior to 1937 was to express the eggs into an enamel or porcelain basin, milt them, and immediately add a little water. The contents of the basin were then stirred and transferred to a larger basin containing water. Here they were left undisturbed until they were no longer adhesive (sticky). In order to obtain an idea of the efficacy of this method and the general quality of the ova at the time, 17 sample batches of eggs varying in size from 124 to 2,195 were taken at intervals through the 1938 season. They yielded an average fertility of 43 percent; individual batches varied between 80.1 percent and zero. More significant still, however, was the fact that a percentage of only 34.2 percent of eyed ova was being produced.

A set of experiments was consequently carried out to test variations in the stripping technique.

Males and females were stripped simultaneously into 50 cubic centimeters of water, but with negative results. The hens were then stripped first into 50 cubic centimeters of water and milt added, but with similar results. Finally, the hens were stripped into a 50-cubic centimeter suspension of milt but the results were also negative. The above experiments are variations of the old "wet" method of impregnation, in opposition to which is the "dry" method discovered as far back as 1856 by Vrasski in Russia.

The dry method as employed at the Ceylon Hatchery (Fawke, 1935) was next tested. A hen was stripped, as many eggs as possible being taken without undue pressure. Milt was expressed over these eggs, the mixture stirred, and the contents of the basin left undisturbed for 5 minutes, whereupon clean water was added to wash the eggs free of milt. They were placed in a large basin, submerged in a trough of running water and stirred at intervals until they separated (lost their adhesive power), this process being known technically as "washing." Subsequently a special washer was devised for the purpose (Inland Fisheries Department Report No. 3, 1946). Ten batches of eggs varying from 105 to 326 gave a mean percentage fertility of 83.5 and individual batches varied between 94.6 and 67.4. This result was so promising that the test was made more intensive in the 1939 season and a control by the old wet method was taken in each experiment. The 12 test batches gave a mean percentage fertility of 89.4; and individual batches varied between 73.4 and 98.6 percent, whereas the control gave a mean percentage fertility of 53.9, individual batches varying between 22.4 and 83.1 percent. On the basis of these results, the variation of the "dry" method of impregnating the eggs as described above was used in preference to the existing method from the 1940 season onwards. The relatively high variation in fertility which obtained notwithstanding improved stripping technique, however, indicated that the solution to the problem did not lie in this direction alone and proved the need for further research.

Investigation was next directed to determining whether or not eggs

were forced from the fish before they were ready to be shed. In nature the hens ascend the smaller side streams, choose a suitable gravel bed for spawning, and commence making a redd. It was therefore assumed that a hen netted off the redd must be ripe.

A number of hens were placed in a pond fed by a long stony race suitable for spawning. Any hens running upstream and beginning to make nests were trapped and stripped by the "dry" method. Six hens were collected in this way and of these two were far from ripe. The remainder gave a mean fertility of 51.1 percent. These naturally run fish therefore produced as poor results as the fish netted in the normal way.

Two factors related to stripping technique were next investigated. When trout eggs ripen they fall free into the body cavity. Should the hen be stripped it is presumed that those nearest the vent will be expressed first, those in the middle next, and lastly those at the upper end of the body cavity. Are all these eggs equally fertile? A hen apparently ripe, was stripped completely into three basins, fertilized with the same cock and the fertilities recorded for each group. The experiment was replicated six times, varying the order in which the milt was applied. In each case the fertilities of the three batches differed. In three experiments the first batch recorded the highest fertility, the greatest variation being 8 percent on a batch of 700. In the other three the second batch was the most fertile, the greatest variation being 10 percent on a batch of 600. Under the circumstances, therefore, this difference is not considered significant. In all tests, however, the third batch to be stripped recorded the lowest fertility, the variation being 3 percent to 21 percent. It is therefore submitted that all the eggs in the body cavity are not in the same degree of "ripeness" and that those lying at the upper end (near the head and the last batch to be stripped) are the "greenest." Furthermore, when the eggs fall free into the body cavity they must remain there for a time before they reach the optimum stage of development for stripping and subsequent artificial impregnation.

Numerous experiments were carried out in an effort to determine how and at what rate this "ripening" takes place. The procedure adopted was to express small batches of eggs from a hen at intervals of from ½ to 2 days, commencing as soon as the eggs begin to run and continuing as long as the supply lasts. No definite conclusions could be drawn from these experiments as regards the potential fertility of the eggs within the first 5 days after softening (the technical term employed to denote the stage when the ova fall free into the body cavity). It was established beyond doubt, however, that after 7 days fertility declines rapidly and that the ova can become overripe. The first visible indication of such overripening is an increasing amount of ovarian fluid in the fish. Thereafter the eggs develop an opaque area which is afterwards clearly visible as a white disc lying on the yolk. At this stage the eggs are completely infertile and if stripped into water the ovarian fluid coagulates as a white precipitate. In some cases these overripe or "white-spot" eggs may be carried over a season or more

and in others they soften, become flaccid and after a few months only the shells remain in the body.

On the basis of these experiments in addition to those described in a preliminary paper (Hey, 1939), the following theory relating to the development of the ova in the body cavity is submitted in Figure 1. Commencing with the immature ova in the ovary, growth and development take place until the stage is reached where the follicles burst and the ova fall free into the body cavity. As the eggs do not all develop at exactly the same rate, however, a few must ripen first, followed by the majority and a small percentage ripening last. This sequence is represented diagram-

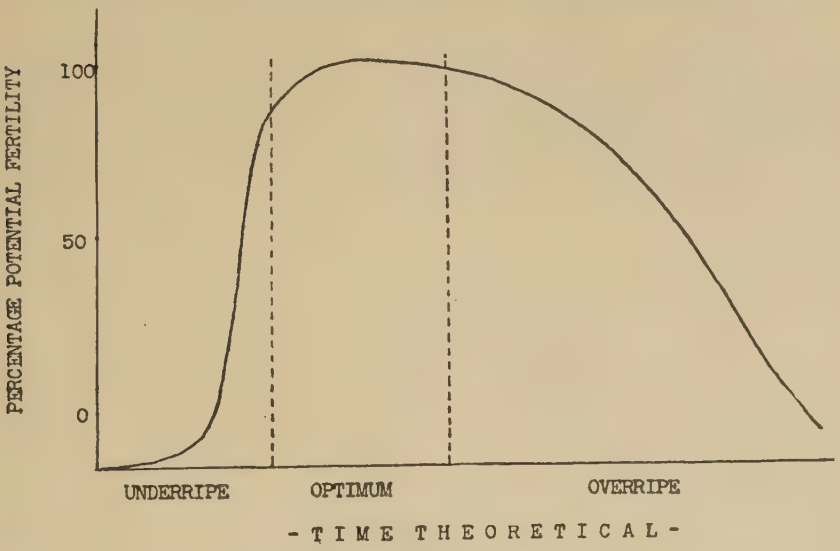

FIGURE 1.—Hypothetical curve to illustrate ripening of ova.

matically as a curve commencing with initial infertility and then rising very sharply to complete ripeness. The first phase, therefore, may be regarded as a period of infertility due to unripeness, the second phase as one of optimum fertility. It is assumed that under natural conditions, the fish would spawn at this stage. The duration of this phase is in all probability inversely proportional to the temperature, the lower the temperature, the longer the eggs retain their potential fertility and vice versa.

The third phase is a period of decline, the eggs, as it were, gradually dying off. Towards the latter quarter of this phase the eggs have declined to such an extent that they yield a very poor percentage fertility and the majority of eggs fertilized produce weakly developed embryos. At the latter end of this phase the eggs are totally infertile due to overripeness, and as they become older they begin to decompose. An excessive amount

of ovarian fluid and a "white spot" in the egg itself are the first visible signs of this decomposition. The eggs then become flaccid, the amount of fluid increases, and eventually only the empty shells remain in the body cavity. For practical purposes therefore, it is essential that the hens be stripped at the apex of this hypothetical curve. All experiments to date would indicate that the period of optimum fertility is short, owing in all probability to the comparatively high water temperatures.

A considerable reduction in the length of the stripping season was effected by stripping regularly at shorter intervals than had been the practice in the past. This procedure had the additional advantage of raising the mean fertility, for it had been observed that there is a marked drop in fertility towards the end of the stripping season which is usually late in July. This trend is represented in Figure 2 where the mean percentage fertility of the best batches taken each week over eight stripping seasons (1938–1946) has been plotted. From this graph it will be seen that there is a sharp rise in fertility from the beginning of the season to a level which remains more or less constant throughout June. Thereafter it begins to drop; this trend becomes very marked from the middle of July onwards.

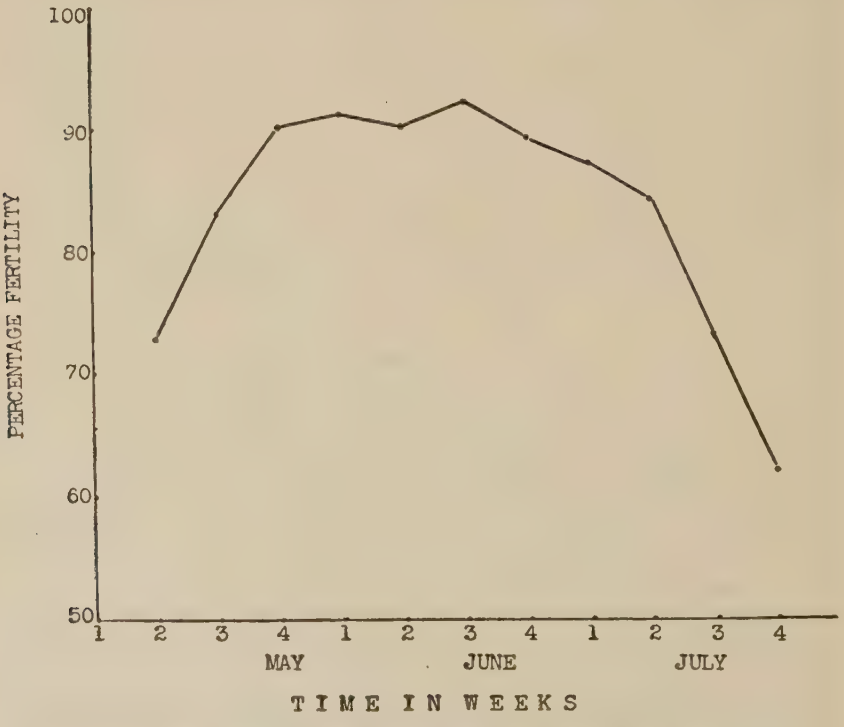

FIGURE 2.—Mean fertility of best batch of ova each week, 1938–1946 seasons.

A study was made also of the behavior of the eggs on the hatching grilles, with particular regard to the incidence of mortality. It was observed that during the first few days after stripping the mortality was low, even in batches of eggs which later proved to be of poor fertility. Thereafter mortalities increased appreciably, reaching a very pronounced peak, and fell away again. A small rise in mortalities occurred again just before the ova are washed prior to despatch. From daily records kept in the hatching house it has been possible to compile a graph (Fig. 3) to illustrate this tendency. Although such a graph gives no indication of the actual mortality, it shows without doubt that the maximum mortality in any one batch of eggs can be expected on the ninth day after impregnation, the variation being from the seventh to the tenth day.

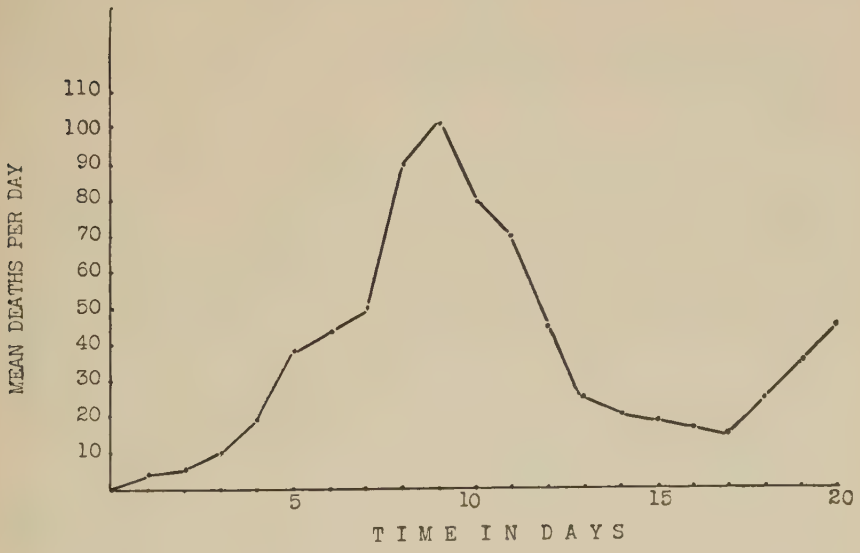

FIGURE 3.—Mean mortalities per day in 12 batches of eggs totalling 110,461.

This fact is of direct application in the hatching house in the allocation of ova supplies. Whereas estimates of the quantity of eyed ova based on initial strippings have been found to be unreliable due to subsequent large mortalities, an estimate based on the number of ova remaining on the grilles 10 days after stripping is far more accurate. This ability to estimate potential yield is most important as consignees frequently wish to be advised a week or more before despatch of their ova and postal connections can be made only on certain days.

From the 1938 stripping season an estimate of the mean percentage fertility of the brown trout ova was obtained by keeping records of batches of eggs selected at random from the ova stripped in the normal way during

the season. Time did not permit the maintenance of a complete record of each batch of eggs stripped. These results are given in Table 2.

From the data in Table 2 it will be seen that the quality of the ova improved steadily from 1938 to 1943. From 1943 onwards there was less fluctuation in fertility. This trend is also reflected in the percentage of

TABLE 2.—*Mean fertilities of brown trout ova, 1938–1946 seasons*

Season[1]	Number of batches	Total number of ova	Fertility (percentage)	Well developed (percentage)	Variation in fertility (percentage)
1938	17	9324	43	34	0 to 80
1939	14	23154	67	55	17 to 89
1940	18	21068	74	55	18 to 89
1941	15	14096	79.6	66	53 to 94
1942	22	37764	80	63.5	48 to 97
1943	29	66521	88	75	77 to 98
1944	21	56013	81	73	75 to 93
1946	13	78816	86	82	74 to 98

[1] No record for 1945

well developed eyed ova produced. The rise in fertility up to 1943 is attributed to the general improvements in stripping and cultural technique which have already been described.

It must be stressed that all improvements in cultural technique were introduced gradually and that there was no drastic changeover from one system to another. Consequently there can be no dramatic jump in fertility. It is claimed, however, that the results given in Table 2 are a true reflection of the efficacy of the general improvements in trout culture which have been introduced as a result, and during the course, of the present investigation. The figures prove a general upward trend, both in general fertility and in the percentage of well developed eggs produced.

The figures for 1946 which incidentally was the most favorable season ever experienced at this hatchery both from the viewpoint of output and fertility, are considered most significant. The high fertility and high percentage of well developed ova is attributed not to the above-mentioned factors alone but also to the cumulative effects of improved feeding of the stock fish. As will be described later, attention was devoted to the feeding of the stock fish from the 1940 season onwards.

While the great variation in the fertility of individual batches of eggs is most unsatisfactory, yet it has been found possible to raise the mean fertility to above 80 percent and to maintain it at this level for five seasons. At the same time a steady improvement in the production of eyed ova has been effected; the 1946 season in particular was most promising.

Diet.—Prior to 1940 the feeding of the trout stock was irregular and food varied greatly in quality and quantity. This irregularity was due chiefly to scarcity of supplies, transport difficulties and lack of funds. Consequently the condition of the stock fish was below normal and this it

was thought might be a contributary cause towards the low fertility of the eggs.

From 1940 onwards an attempt was made to improve the diet of the trout stock. The food selected was based on the recommendations of Wiesner (1937) and consisted of a mixture of two parts of fresh liver and lungs and one part of sea fish. For this purpose "stock-fish" (*Merluccius capensis*) was used as it was the only variety of fish in regular supply. The liver and fish were mixed (the particles used were as large as the fish could conveniently consume) thoroughly with a pinch of lime in an attempt to compensate for the deficiencies of the acid water. Once a week the spawners (hens) were given a limited weight of the fresh marine white mussel (*Donax serra*). Live food such as tadpoles, forage fish, maggots, etc. was used whenever possible but unfortunately only in small quantities.

All fish were measured and weighed prior to being placed in the holding ponds (summer ponds) and again immediately prior to the stripping season. Consequently the number and total weight of fish in the stock ponds was always known and it was possible to feed 5 percent of the total body weight in food daily. It was assumed that as all fish were of reasonably uniform size and the food was widely scattered in feeding, each fish would receive a fair proportion.

Feeding was as regular as possible—at 8:30 a.m. with the exception of Sundays and those odd days when food supplies failed.

When the hens were examined at the commencement of the 1941 stripping season there was a noticeable improvement in condition and the eggs were larger in size (5.0 to 5.3 millimeters diameter). By the 1944 stripping season all the hens were in superb condition. Ova production averaged over 900 per pound of body weight and the eggs appeared perfect. Furthermore they stripped with ease. Despite appearances, however, as will be seen from Table 2, fertility decreased. This drop was attributed to the males which were in lean condition. Prior to 1944 no change was made in the diet of the cocks and during that stripping season not only was great difficulty experienced in obtaining sufficient milt but the little obtained was variable in quality.

From the 1945 growing season the males were placed on the same diet as the females and the rise in the fertility of the ova during the following stripping seasons would indicate that it is important that the males be as well fed as the females.

The improvement in the diet of the stock fish described above is considered a contributary cause towards improving the fertility of the brown trout ova.

Genital system of the male.—The genital system of male brown trout at the Jonkershoek Hatchery appears upon dissection to be normal. The quantity of milt delivered, however, is very small compared with rainbow trout (*Salmo gairdnerii*), but this may be characteristic of the species. A comparison with conditions at institutions elsewhere would be interest-

ing. Another difficulty experienced is that the hens ripen before the males and little, if any, milt can be obtained for the first batches of eggs. This difference of timing may be due to the fact that the two sexes are kept separate during the summer, for within a week after the cocks are placed with the hens in the stripping tank, they ripen.

The viability of the milt has been examined microscopically on a number of occasions. Using a sterilized needle, a small quantity of milt was placed in water of known temperature under the microscope and the average life of the sperm timed in each case. These experiments established the fact that the life of the milt is in inverse proportion to the temperature of the water and that above 10°C. it does not exceed 60 seconds (Hey, 1940). Occasionally males yield lifeless milt which might account for the total infertility of some batches of eggs.

The above findings were corroborated by a further experiment. A suspension was made from the milt of four males in 250 cubic centimeters of water. This suspension was then added to seven batches of eggs (from the same hen), the time being noted in each case. The sperm had been in water for 23 seconds before the milt suspension was added to the first batch of eggs. All batches of eggs to which milt suspension not older than 40 seconds was added were reasonably fertile, at 60 seconds only 1 percent of the eggs were fertilized and thereafter none. At 10°C., therefore, while the life of individual sperm in water may be as long as 60 seconds, the effective life of the milt does not appear to exceed 40 seconds.

Microscopic tests of the milt each season indicate that not only does the quality of the milt from individual fish vary, but there may be a general seasonal variation. For example, as described above, during the 1944 season a meat shortage was experienced and the diet of the hens was maintained at the expense of the males. The result was that while the hens produced fine-looking eggs and stripped clean, the fertility was decidedly lower than the previous season. Examination of the milt established the cause. Reduction in quantity of milt, however, is not as serious for it has been found that very little is required to fertilize a batch of eggs. Two drops are sufficient for over a thousand eggs.

At the end of each spawning season the males are sorted and all defective and large fish are disposed of. Only breeders under 4 years old are kept. Larger males are considered uneconomic as the older they become the more food they require and the less milt they produce. The ratio of the sexes carried is one male to two females and this proportion has been found satisfactory.

Genital system of the female.—Numerous dissections established the fact that the female stock fish are normal anatomically. As they become older, however, the number of ova produced drops and not infrequently the fish become egg-bound. I am unable to agree with the findings of Kendall (1921) who claims the presence of an oviduct in trout. A description of the female reproductive system as interpreted from the hens at Jonkershoek is given in an earlier paper (Hey, 1939).

The quality of eggs from first spawners at this hatchery is most variable. In a few fish it is high whereas in others it may range from fair to total infertility. Furthermore, "white spot" is not infrequent. In each fish of low fertility the eggs are small and pale (4.1 millimeters in diameter). In this connection Day (1887) stated: "For several seasons it has been remarked at Howietown that eggs from young mothers were subject to a greater percentage of deaths than those taken from older fish." For the first spawning season, therefore, a hen is of little value as a potential producer of ova and cannot be taken into consideration in the estimation of the potential yield from the hatchery.

At Jonkershoek hens are considered to be in their prime, both from the viewpoint of quality and quantity of ova, from the second to the fourth spawning season. From then onwards the eggs increase in size and decrease in number. The fish strips with difficulty as the abdominal wall does not "soften up" as normally happens at this season. Consequently there is a tendency for these older fish to carry their eggs over, finally resulting in the state of congestion described in a preliminary paper (Hey, 1939).

In this connection it is interesting to note a report by Scott as far back as 1902. "During the past season the spawning was not so good as was anticipated and the females, considering the condition they were in, did not yield anything like the quantity of ova they should have done, and a considerable number did not spawn at all. The reason for this was on account of the ovaries being congested, due, no doubt, to the food on which the fish were fed. Owing to the scarcity of local supplies of fresh food, it was necessary to use imported plucks, which, when thawed seemed to have lost some of their nourishment. This congestion of the ovaries was most noticeable among the Loch Leven trout, the rainbow trout giving their ova more freely; but among the latter there was a large percentage of bad eggs."

The average age of a spawner at this hatchery is 7 years, with the optimum utility from the third to the fifth year. For this reason the fish are carefully sorted at the end of the stripping season and all defective, old and abnormally large fish are disposed of. Those selected for stock are returned to the pond where they are carried until the next spawning season.

Pathological conditions.—During the seasons under review both fish and eggs were remarkably free from disease, whether merely due to chance or because of the healthful living conditions will only be established later.

During the hot summer months there is always a certain mortality of stock fish, confined almost entirely to the old hens. On the stripping table 1 to 2 percent of the hens will produce dead eggs mixed with a mass of bloody ovarian fluid; the cause is unknown.

In the hatching house as indicated in previous tables, a proportion of the eggs die, due either to initial infertility or to organic weakness. These eggs turn white and must be removed daily. If they are not removed threads of *Saprolegnia* sp. appear by the second day and spread to the surrounding eggs. If the focus is removed, however, and the threads

broken, the live eggs to which they were attached do not appear to suffer unduly.

"White spot".—As proved experimentally, "white spot" is the first visible sign of decomposition in the egg. It appears as a small opaque area lying in or on the yolk. This area gradually increases in size and may assume a variety of shapes as illustrated (Hey, 1940). Eventually the whole egg becomes opaque and vacuities become visible in the yolk. Numerous oily globules of an amber color then appear; repeated attempts were made to section these eggs using a variety of fixatives, but invariably the yolk was too hard and brittle. Microscopic examination, however, indicated that "white spot" is caused by the degeneration of the yolk.

"Bursting eggs".—Occasionally a batch of eggs may be stripped, of which a large proportion burst as development proceeds. The yolk sacs of a percentage of the fry that hatch exhibit a similar phenomenon. The cause of this bursting is unknown but it has been observed that the eggs are very thin shelled.

Blood spots.—A peculiarity of certain batches of eyed ova is the presence of blood "spots" or contusions. These spots may vary in size, number and shape. Furthermore such a spot may be isolated or may commence as an enlargement of an existing blood vessel. The majority of such eggs die but a small proportion do hatch. In these instances, the blood contusion can be seen on the surface of the yolk sac, and it gradually diminishes in size as the yolk sac shrinks. It has not been possible to establish the cause of this disease as yet, nor whether it is due to a condition of the eggs themselves or to an organic weakness on the part of the parents.

Dropsy.—Dropsy is relatively common in the hatching troughs but losses from this source are not heavy.

Deformities.—A small percentage of deformities occurs each year among the alevins. These abnormal young are chiefly twins or suffer curvature of the spine.

Climatic factors.—As a result of the generous assistance of the Chief Forest Research Officer, Jonkershoek, it has been possible to make a reasonably complete study of certain climatic factors at this hatchery, namely streamflow, rainfall, temperature, acidity, oxygen content, and silt content. I am greatly indebted to Dr. C. L. Wicht, the Forest Research Officer, for placing his records at my disposal and for his assistance in the compilation of the results, full details of which are given in previous papers (Hey, 1940 and 1941).

From these data it was concluded that, although the ecological factors such as streamflow and temperature are by no means optimum, none of the factors investigated presented definite obstacles to the culture of brown trout. Nevertheless it is possible that the combined effect of a number of adverse conditions might lower the vitality of the fish, which would in turn affect the quality of their ova.

General Conclusions and Discussion

The results of this investigation may be summarized as follows:

1. The fertility of the ova was raised by a modification in stripping technique. An appreciable reduction in the length of the spawning season was effected by stripping at 2-day intervals and sorting the stock fish regularly. It has been established beyond doubt that one cannot rely on the hens running up when they are ripe. If the weather is propitious a percentage will do so, but if not, they remain in the stock pond where they either shed their eggs or retain them in the body cavity until they overripen.

2. There is a period of optimum fertility for each hen at which stage the eggs should be stripped. Owing to the comparatively high water temperatures, this period is a short one. Eggs stripped prior to this period may be infertile due to underripeness, whereas those stripped after may be overripe.

3. The mean fertility differs during the stripping season. From the beginning of the season there is a rise to a broad peak in the middle of the season, whereafter there is a rapid decline.

4. The maximum mortality in any one batch of eggs can be expected on the ninth day after impregnation, the variation being from the seventh to the tenth day.

5. The genital system of the male is normal and the effective life of the milt in water does not exceed 40 seconds.

6. The genital system of the female appears to be normal.

7. Improvement in the quality of the breeders has been effected by rigid selection at the end of each stripping season.

8. By improving the diet and by regular feeding, the stock fish have gained in condition, the yield of ova has been raised, and the eggs strip with ease. Good feeding of the cocks is as important as that of the hens.

9. Although ecological factors such as streamflow and temperature are by no means optimum, none of the factors investigated presents a definite obstacle to the culture of brown trout.

From the foregoing it will be evident that while an improvement in the fertility of the eggs and general condition of the breeders has been brought about, the problem of the low fertility of the brown trout ova at this hatchery has by no means been solved. Further improvements may not be possible owing to the limitations of climate. One stimulating fact, however, is that while the mean is just over 80 percent, the fertilities of individual batches vary. Not infrequently fertilities of 98 percent have been recorded. This leads one to hope that it will become possible to raise the general standard to this level. Without first-hand information on the condition at other trout hatcheries, it is difficult to judge the quality of ova and relative fecundity of the Jonkershoek trout. It is therefore felt that this investigation has now reached the stage where it is necessary to visit

similar institutions in other countries in order to draw comparisons and collect information on the basis of which further lines of research can be planned.

Acknowledgements

I wish to express my thanks and appreciation to Dr. C. L. Wicht for placing the ecological data at my disposal and for his generous assistance in the interpretation thereof.

To Messrs. du Plessis, Blommaert, and Col. Page of this Department for their willing assistance in keeping hatching-house records. Without their assistance it would not have been possible to collect such a wealth of data.

To Mr. A. C. Harrison of the Department for furnishing the material for the historical background.

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ESTIMATING THE FISH PRODUCTION OF GREAT SLAVE LAKE

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Abstract

A biological survey of Great Slave Lake was begun in 1944 in order to estimate its capacity for fish production before commercial fishing began. This great inland lake of 10,500 square miles was found to have a fairly heavy population of desirable fish with lake trout, lake whitefish, and ciscoes predominating. Physical, chemical, and biological evidence suggested a capacity for sustained production not unlike that of the upper Great Lakes and Lake Nipigon. A first estimate of 3 to 5 million pounds per year was made in December 1944. Commercial fishing began in 1945 and has now increased to a point where production is 3.7 million pounds per year. General biological studies extended over 4 years, and a continuing program has been established to follow the effects of fishing on the fish population. This lake affords a unique opportunity for the scientific investigation of a large fishery and for the conservation of an important natural resource.

Introduction

The fishery investigation of Great Slave Lake has been part of a larger program to provide information needed for the development and conservation of natural resources in northwest Canada. Great Slave, the fifth largest of the great inland lakes of America, had never been fished commercially. It was necessary to find out whether it would support a commercial fishery in addition to the extensive domestic catch. Here also was a magnificent opportunity to study a virgin lake, to plan for the utilization of its fish and to explore the scientific aspects of fishery management on a large scale.

The survey was begun in 1944 and has continued through 4 years. For the field work a floating laboratory and two specially equipped power boats were built. These vessels were used by a field party varying from 5 to 10 in the different seasons. The work is now completed, a commercial fishery is established on the lake, and we have set up a continuing program for the study of the commercial catch and management of the fishery. A general account of the survey has already been published (Rawson, 1947). The present paper is a description of the procedure followed in estimating the productive capacity of the lake.

Methods

Most fishery biologists will agree that a considerable gap still exists between our growing knowledge of the dynamics of aquatic production

and the application of this knowledge in the estimation or prediction of a fishery. It was not expected that any accurate prediction of the fish-producing capacity of Great Slave Lake could be made. There was, however, an urgent problem, and our responsibility was to give the best estimate of which we were capable in a reasonable time. It could be regarded as a challenge, to see how far our limnological methods could be applied in this practical problem.

Our procedure was to investigate all sources which might provide useful information. Thus the whole area and depth of the lake was studied to determine the extent of productive areas. Physical and chemical studies were confined to those believed to be most significant in relation to biological productivity. Quantitative sampling of plankton and bottom fauna was carried on in all parts of the lake. The fish were sampled extensively by means of gangs of gill nets. Detailed analyses of the fish catch were made to study composition, density, distribution, rate of growth, and quality. Finally, careful comparisons were made between conditions observed in Great Slave Lake and those in other large, deep lakes from which commercial fish production was known through many years of fishing.

General Summary of Observations

Each of the lines of investigation mentioned above has produced much material, most of which has been analysed and will be reported on in several studies now in preparation. It will suffice here to summarize the results of these studies and to suggest some of the ways in which the information has been applied.

Analysis of the morphology of the lake has been a considerable problem. Its total area is 10,500 square miles, from which we can deduct at least some 700 square miles of islands. We shall see later that, from the viewpoint of fish production, we could also deduct an area of about 800 square miles which is more than 500 feet deep. The remaining 9,000 square miles is still a large water area. Most of the fishing is done in the western portion of the lake and in the north arm (see Fig. 1). Most of these areas are less than 200 feet deep and the mean depth is 120 feet. The east arm, which is much broken by islands and large peninsulas, is very deep (mean depth 440 feet). The Hearne Channel is more than 1,000 feet deep, McLeod Bay over 900, and Christie Bay over 2,000 feet. In the latter area more than 85 square miles exceed 1,000 feet and about 10 square miles are 2,000 feet deep. The irregular shoreline, more than 2,000 miles long, is also of interest in fish production since it provides shelter both for fishermen and for fish. The precambrian shores to the north and east are mostly rocky and rather barren. The lower shores of the west and south are mostly shallow and subject to heavy wave action.

Water temperatures in Great Slave Lake are decidedly cold. The surface temperature of the open lake at midsummer is rarely higher than 50° F. In the east arm it is often only 40° but in shallow water along the south shore and near the delta it sometimes rises to about 60°. Deep-water

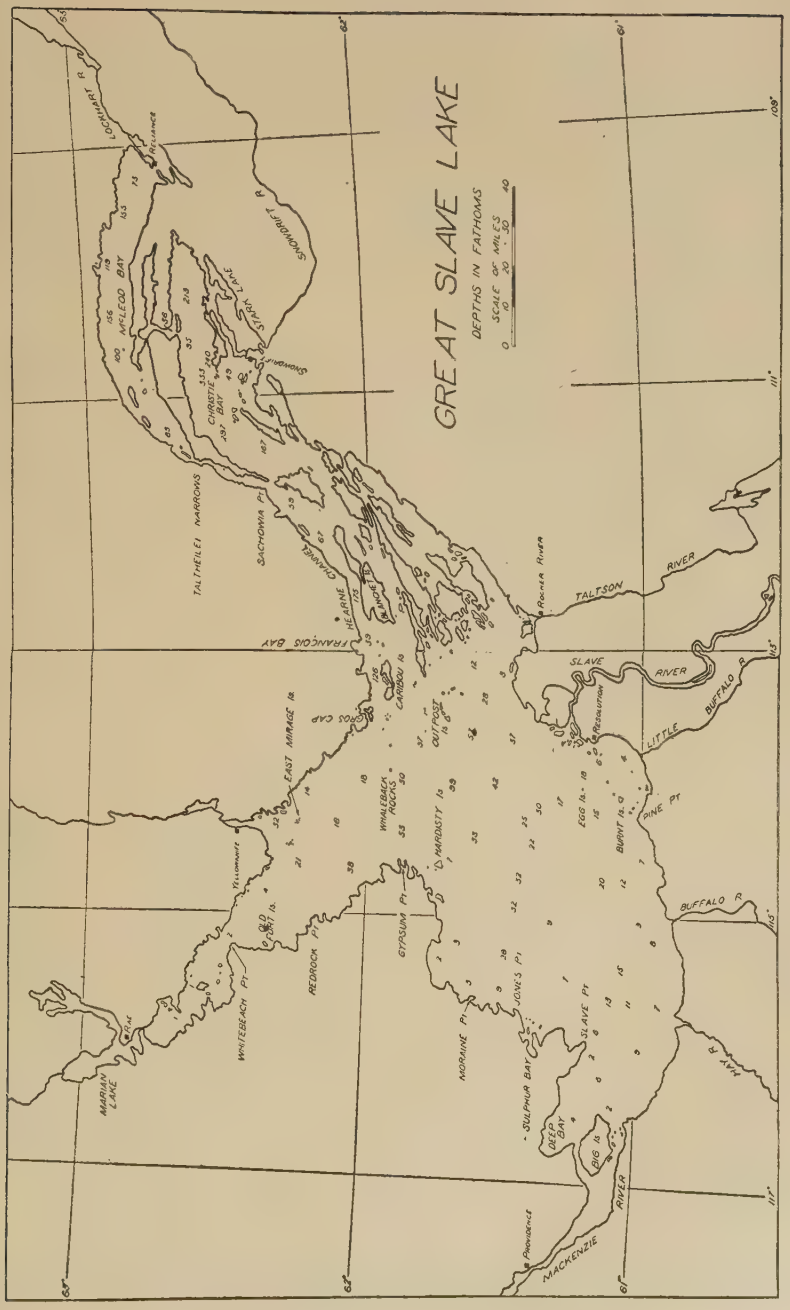

FIGURE 1.—Map of Great Slave Lake showing depths.

temperatures are extremely low, about 40° at 100 feet and 38.5 at 2,000 feet. Mean temperatures are also very low, about 41° F. in the east arm and 46.6° F. in the central and western parts. It has been found elsewhere (Rawson, 1942) that the mean temperature of the upper 33 feet (10 meters) shows more correlation with basic production of plankton than does the mean of the whole lake. The average mean temperature of the upper 33 feet in the central and western part of the lake during July and August is about 46° F. The growing season is rather short because ice covers most of the lake for 6 or 7 months. The seasons differ greatly between Reliance at the extreme east end of the lake and the outlet of the lake which is 250 miles to the west.

The abundance of plankton in arctic marine waters warns us against casual association of low temperatures with low productivity. Nevertheless we have observed in Great Slave Lake greater quantities of plankton in the warmer western and southern waters than in the cold east arm. Also, as noted below, the rate of growth of the whitefish is appreciably faster in the south part of the lake than off the rocky north and west shores. No doubt some factors other than temperature are involved in these differences.

Physical and chemical factors other than temperature have been investigated. Mineral analyses show that the water is dilute—total solids from 22 to 170 p.p.m. Turbidity varies from extreme transparency in the east to high turbidity in the silt-laden waters off the Slave River delta. Dissolved oxygen is always plentiful, usually between 80 percent and complete saturation. The lake can be "typed" both physically and biologically as an example of extreme oligotrophy.

The plankton of the lake may be described as of moderate quantity. The standing crop throughout the growing season averages about 23 pounds, dry weight, per acre. About 60 percent of this weight is organic matter. The bulk of the crop is found in the upper 100 feet but a significant population of copepods is present even down to depths of 2,000 feet. This crop of plankton is low compared to warmer lakes of a eutrophic type. It is somewhat greater than that found in alpine lakes of the Rocky Mountain region (Rawson, 1942) and in general is much as one would expect in a large northern lake. The dominant phytoplankters are the diatoms, especially *Asterionella, Melosira,* and *Tabellaria.* Abundant zooplankton forms were the copepods *Limnocalanus, Diaptomus,* and *Cyclops,* and the rotifer *Keratella.* General similarity was noted to the plankton of other large deep lakes studied in North America. Two periods of great production, which may be compared to the accepted spring and fall maxima, have been observed. However, in the short growing season of Great Slave Lake, these periods tend to come close together. This was particularly noticeable in 1947 when the breakup of the ice was unusually late.

Present techniques for the measurement of plankton populations are not regarded as satisfactory and our knowledge of what may be called the dynamics of production is just developing (see Clarke, 1946). However,

if our plankton data are not of much use in predicting the fishery we can reverse the procedure and point to the heavy population of ciscoes as evidence of the adequacy of plankton production. In McLeod Bay, where excessive depth reduces the bottom-fauna production to an almost negligible quantity, no lake whitefish are found. However, a considerable trout population is supported on the plankton→cisco→lake trout food chain, *i.e.*, a limnetic productivity exists relatively independent of the benthic community.

The bottom fauna was sampled extensively with 600 quantitative

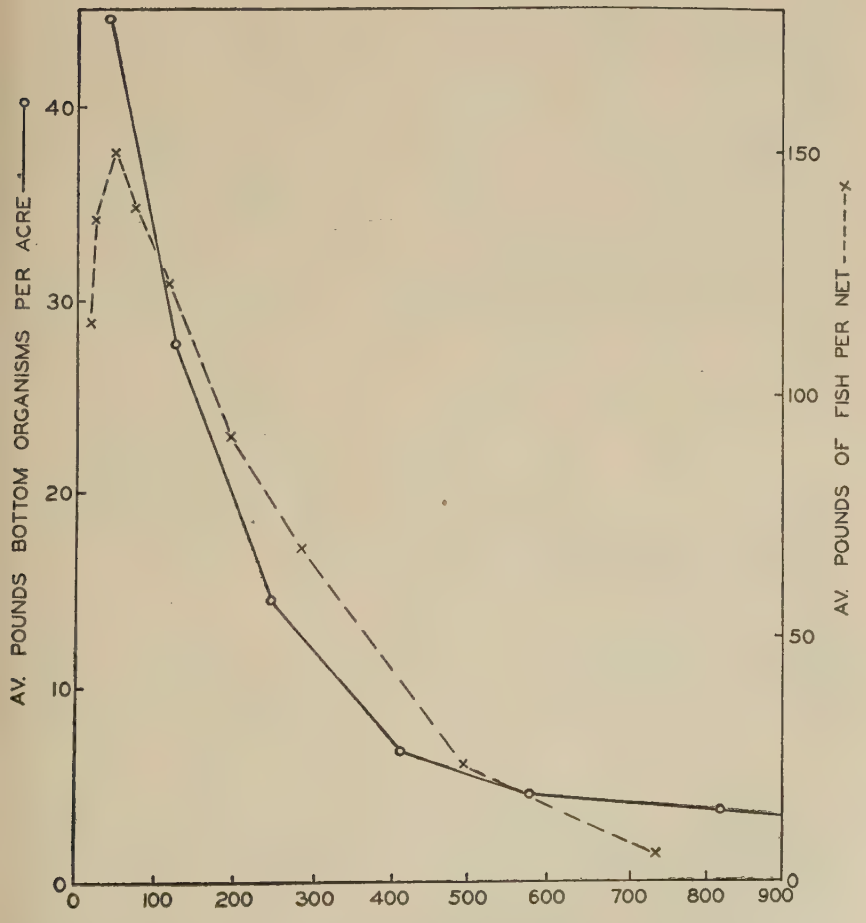

FIGURE 2.—Average weight of bottom organisms caught at various depths in Great Slave Lake, compared with the average weight of fish caught in standard nets at the same depths.

dredgings taken from all depths and areas. The average population is about 1,300 animals per square yard, weighing 28 pounds per acre (about 3.4 pounds dry weight per acre). The amphipod, *Pontoporeia hoyi,* is the dominant form, contributing about 65 percent of this weight. Oligochaete worms, chironomid larvae, nematodes, ostracods, and sphaeriids are also numerous and widespread. The importance of this benthic fish food is evident from the examination of fish stomach contents and is strongly implied in the depth-distribution curves for fish catch and quantities of bottom organisms in Figure 2. The close correspondence of fish catch with quantity of bottom organisms invites the derivation of a mathematical correlation. Alm, as early as 1923, attempted such a correlation in his Fb (Fishbenthos) coefficient for lakes in southern Sweden. It is doubtful, however, whether such treatment is of much value in the absence of more complete data as to all stages and kinds of production.

A striking similarity was noted between the species found in the bottom fauna of Great Slave and those of Lake Michigan (Eggleton, 1937), Lake Superior (Eddy, 1943), and Lake Nipigon (Adamstone, 1924). The dominant species in each was *Pontoporeia hoyi* and the quantities of all organisms per unit area were closely comparable, a helpful situation in attempting to assess fish-producing capacity.

The fish of Great Slave Lake represent some 23 species of which the larger and commercially significant are listed in Table 1. This table sum-

TABLE 1.—*Numbers and weight of fish caught in 145 standard gill-net sets in Great Slave Lake, 1944–1946*

Species	Numbers		Weight (pounds)	
	Total catch	Per-centage	Total catch	Per-centage
Ciscoes, *Leucichthys* spp.	4,721	40.2	1,437	7.3
Lake whitefish, *Coregonus clupeaformis*	4,305	38.0	5,589	28.3
Lake trout, *Cristivomer namaycush*	1,204	10.2	9,023	45.8
Longnose sucker, *Catostomus catostomus*	476	4.1	950	4.8
Round whitefish, *Prosopium cylindraceum*	234	2.0	211	1.1
Pike, *Esox lucius*	211	1.8	760	3.8
Burbot (ling), *Lota lota*	155	1.3	512	2.6
Inconnu, *Stenodus leucichthys*	151	1.3	982	5.0
Yellow pikeperch, *Stizostedion vitreum*	84	0.7	126	0.6
White Sucker, *Catostomus commersonnii*	60	0.5	138	0.7
Goldeye, *Amphiodon alosoides*	12	0.1	3	0.0
American grayling, *Thymallus signifer*	7	0.06	11	0.0
All species	11,620	100.0	19,741	100.0

marizes the catch in 145 24-hour settings of a standard gang of gill nets, 300 yards in length and made up to 50 yards each of meshes 1½ to 5½ inches, extension measure. This gang is "standard" only for our own field work but we have used it for nearly 20 years in a considerable variety of waters and thus have a large amount of comparable data. From the table and still more evidently from the graph, Figure 3, three species are seen to be dominant—the ciscoes, lake whitefish, and lake trout. Ciscoes lead in

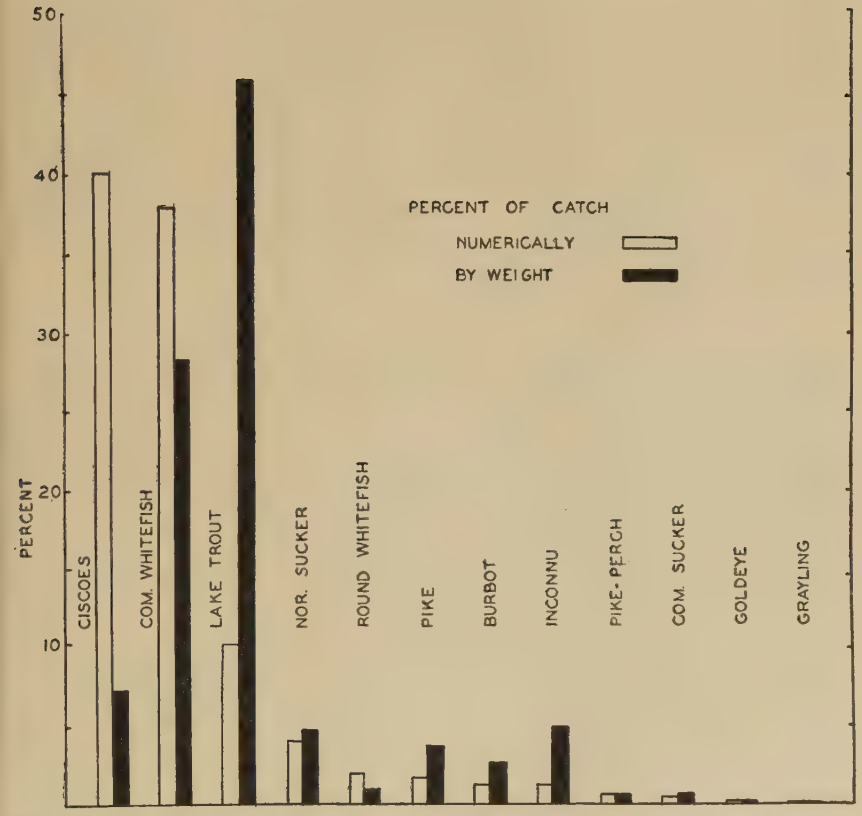

FIGURE 3.—Percentage composition of the gill-net catch in Great Slave Lake expressed numerically and by weight.

numbers but are a poor third in weight. Five secondary species provides some competition for the dominants but are mostly restricted to shallow areas and thus seldom enter the commercial catch in any quantity. This high proportion of desirable fish in the total population is obviously of importance in estimating possible production.

The distribution of the fish population with respect to depth has been indicated in Figure 2. Judging by the gill-net catches, the greatest concentration of fish is at about 70 feet whereas much smaller numbers are found below 200 feet and only negligible numbers beyond 500 feet. Analysis of distribution with respect to area show some areas with heavy population and others like McLeod Bay very lightly populated. Goldeyes and yellow pikeperch are found mostly in the warm south-shore waters; grayling and round whitefish are mostly along the rocky shores of the north and east.

The application of growth studies to our problem can be illustrated by comparative records for the growth of lake whitefish in Great Slave and other waters (Fig. 4). It will be seen that growth in Great Slave Lake is somewhat slower than in Lake Huron (Van Oosten, 1939), and Lake Erie (Couch, 1922). It is almost identical with that of Lake Athabaska (not shown), and considerably faster than in Lake Nipigon (Hart, 1931), both of which support whitefish fisheries. It was also of interest that whitefish from the warmer area near Fort Resolution had grown considerably faster than those taken from the rocky northwest shore toward Yellowknife (a gain of about 1 year's growth in 7).

Comparison with Production in Other Large Lakes

The known production of fish from other large lakes was used in arriving at an estimate of the possible production from Great Slake Lake. Information from the three upper and deeper Great Lakes is most helpful because they have much in common with Great Slave. Lake Superior, for instance, has great depth, extremely low temperature, and bottom fauna which is like that of Great Slave. Similarities to Lake Michigan and Lake Nipigon have been noted above. The same or closely related species of fish are dominant in all these lakes. Thus if, over a period of 25 years, these lakes have produced 1½ pounds of fish per acre it seems reasonable to assume that Great Slave can produce at a rate approaching this figure.

Data from the report of the International Board of Inquiry for the Great Lake Fisheries (1943) indicate that production from all the Great Lakes for the 25 years 1916 to 1940, averaged 112 million pounds. The total area of the Great Lakes is 95,000 square miles; thus annual production has averaged 1,170 pounds per square mile, or 1.8 pounds per acre. Of course a shallow and relatively warm lake such as Lake Erie produces three or four times this amount but if we eliminate these as not comparable, we find that the combined production from Lakes Superior, Michigan, and Huron averages about 1.3 pounds per acre. Lake Nipigon over a 25-year period has produced 1.07 pounds per acre.

It is obvious that in applying these comparisons certain limitations should be recognized and some modifying factors considered. Dividing the catch by the whole area of the lake is a rough procedure when we know that some considerable areas are relatively unproductive, *e.g.*, the extreme depths of Great Slave noted above. However, Rounsefell (1946) has shown that when the known production of a large number of bodies of water is considered, the relation of production to area is capable of a considerable degree of prediction on a mathematical basis. It is probable also that various coarse or less desirable species of fish can be marketed from the Great Lakes which could not be shipped profitably from Great Slave Lake. Fortunately the fish population of Great Slave has a relatively low proportion of these less desirable species. The shorter growth season for the production of fish food and the somewhat slower growth of whitefish and lake trout in Great Slave Lake must be given some consideration.

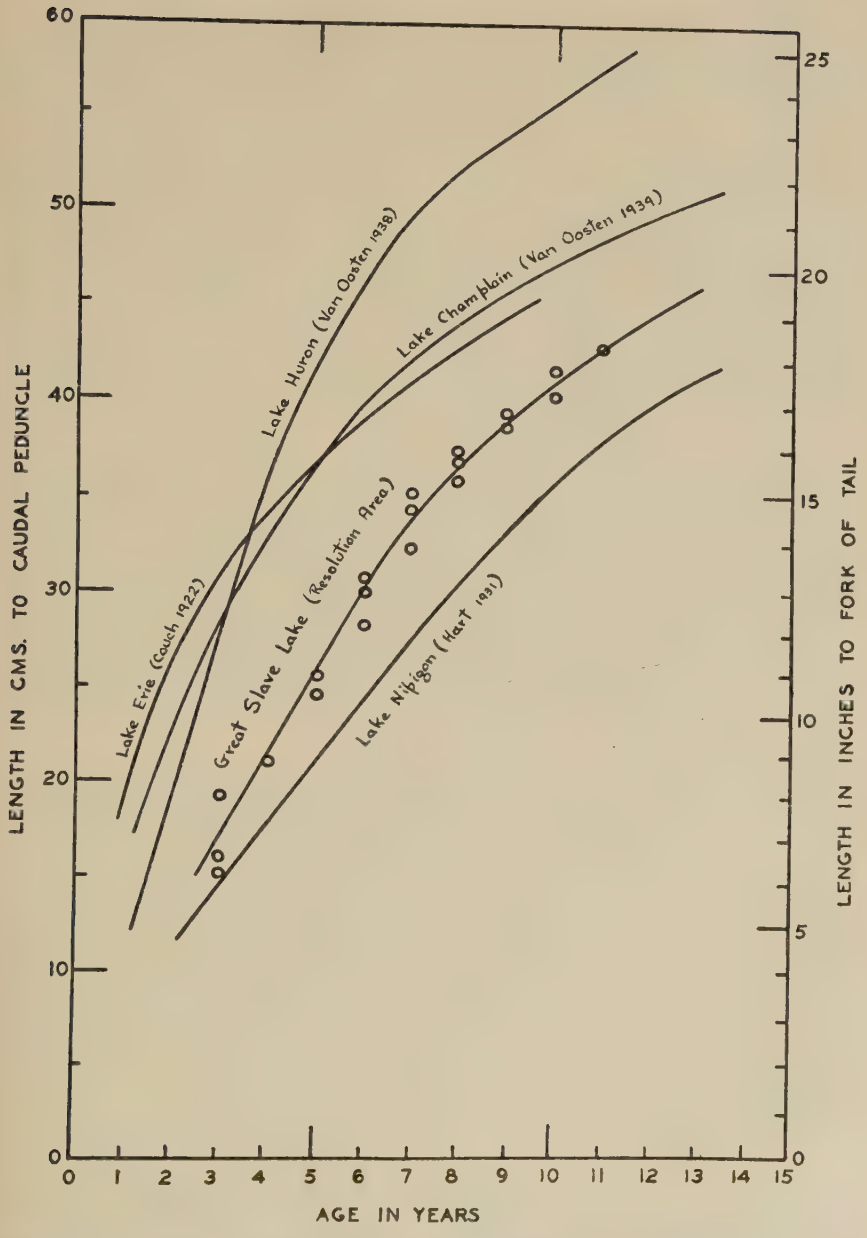

FIGURE 4.—Comparative growth rates of the lake whitefish for Great Slave Lake and other large lakes.

It should be kept in mind also that although these figures indicate sustained yield of these fish they are merely a record of utilization and not an indication of basic productivity. Thus much higher sustained yields might be possible under improved management and favorable marketing conditions.

Following the method of reasoning indicated above, it was decided that Great Slave Lake should be capable of a minimum annual production of from 0.75 to 1 pound per acre or from 3 to 5 million pounds per year. This figure, which was reported to the Department of Fisheries, Ottawa, in December 1944, has been used as the basis for regulation of the fishery. The annual limit set for the commercial catch recognized the great importance of domestic needs for fish. Residents around Great Slave Lake use for human consumption and for feeding dog teams, an amount estimated at from 0.5 to 1 million pounds per year.

Results of Commercial Fishing

Commercial fishing was begun in July 1945 from a central harbor at Gros Cap. In 6 weeks' fishing a total of 1.5 million pounds was taken. In 1946, the catch was 2.5 million pounds, including a small amount taken in the winter of 1946–47. The third season produced a summer catch of 2.3 million and a winter catch of 1.4 million, a total of 3.7 million pounds. This catch is approaching our estimate of the minimum sustained yield and the limit set by government regulation on the annual take. Since the fishing to date has covered only a small fraction, possibly a fifth, of the fishable area it seems probable that a considerably greater annual crop may be taken with safety.

The catch in the past three years has been mostly of lake trout (62 percent), whitefish (33 percent), and inconnu (5 percent). The fish are all of high quality and have commanded a price which more than offsets the cost of production and transportation. The bulk of the catch has gone some 2,500 miles to markets in Chicago or still farther to New York. Although the fishery is located in a somewhat remote area the methods are by no means primitive. The fish are caught in gill nets and delivered promptly at the centrally located processing barge. Here they are dressed or filleted, packaged, and frozen. Much of the catch is handled by quick-freeze units. Some of the summer-catch fish is hauled in refrigerator barges about 500 miles upriver to railhead, some is taken out by transport planes. The winter catch is hauled by trucks to railhead or by planes, much of it in a fresh (not frozen) condition.

The Management Program

The aim of the management program is to maintain the highest level of utilization possible without damage to the stock. The 1944 estimate of possible production was only tentative. Although it has proved to be satisfactory in the beginning years of the fishery, it should be examined

constantly and modified if necessary as the industry progresses. This requires a continuous program of examination and such a program is being carried out under the direction of Dr. W. A. Kennedy of the Fisheries Research Board of Canada.

The first essential of the continuing program is a scheme for the collection of accurate and detailed catch statistics that will permit the calculation of catch per unit effort, in this case pounds of fish per net-night. Each species of the commercial catch is generously sampled to determine the average weight, the rate of growth, and the age composition of the catch. It is felt that these data will provide indices or at least evidence of any important changes in the fish population resulting from the effects of fishing.

The lake trout of the present population grow slowly and include an abnormal proportion of old, large individuals. In the first 3 years of the fishery, lake trout made up about 62 percent of the catch as compared to 33 percent of lake whitefish. It is probable that heavy fishing will reverse this situation. In Lake Superior the piscivores (mostly trout) make up 30 percent of the commercial catch and in Lake Nipigon 25 percent. Improvement in the rate of growth of both lake trout and whitefish may be expected if heavy fishing continues and relieves the "population pressure."

The opportunity of observing the effects of commercial fishing from its inception in a lake of such size is probably unique at this time in the history of the exploitation of our natural resources. We hope to continue to obtain significant information on the effects of exploitation while conserving this great resource.

Acknowledgment

The writer wishes to express his sincere appreciation to the Fisheries Research Board of Canada for the opportunity of directing this project and for the generous support provided throughout the period of investigation. Much credit is due also to the 12 members of the scientific field parties who did excellent work during the summers of 1944 to 1947.

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RESPONSE OF BROOK, RAINBOW, AND BROWN TROUT TO VARIOUS DOSAGES OF SULFAMERAZINE

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Abstract

During experiments in 1945 and 1946 in which sulfamerazine in the food was found to be effective in the treatment of furunculosis in brook trout (*Salvelinus fontinalis*), it was observed that fish grew faster on untreated food and that when the dosage rate was heavy they did not eat all the food and showed a dislike for it. To determine the effect of sulfamerazine treatment on growth and to learn whether the drug injures various trout species, brook trout and rainbow trout (*Salmo gairdnerii*) were tested in 1946 and brown trout (*Salmo trutta*) in 1947. The daily dosage rates chosen were 0, 5, 10, and 15 grams of the drug per 100 pounds of fish (0, 11, 22, 33 grams per 100 kilograms).

It was observed from this experiment that: (1) sulfamerazine was not lethal; (2) the drug had no apparent injurious effect; (3) retardation of growth was caused by reduced consumption of food containing the drug; (4) there was great variation among the three species of trout in their response to sulfamerazine, *e.g.*, the growth of rainbow trout was not affected, growth of brook trout was reduced by heavier dosage rates, and growth of brown trout was stopped by 5-gram or greater dosage rates; (5) hemoglobin and number of erythrocytes increased in brown trout treated with sulfamerazine in the food; (6) a very small dosage, begun in time, appears to be sufficient to control furunculosis in brown trout.

Introduction

In a series of experiments designed to test the effectiveness of sulfamerazine for the treatment of furunculosis in brook trout (Gutsell, 1946, 1947; Gutsell and Snieszko, 1949), it was observed that the fastest growing fish were the controls which did not receive the drug. This faster growth was caused in part by the higher availability of food to the controls but, because there was a marked reduction in the food consumption of fish treated with sulfamerazine, it was assumed that the drug retards growth.

It was noted further that fish dying from causes other than *Bacterium salmonicida* were more numerous in the treated lots than in the controls. Mortality was highest in the lots treated at the highest rate (12 grams of sulfamerazine per day per 100 pounds of fish). These results suggested that the 12-gram rate was dangerously high.

To find an answer to the questions thus raised and to broaden our understanding of the problem, new series of trials were run in 1946 and 1947. The daily dosage rates chosen were 0 (controls), 5, 10, and 15 grams of sulfamerazine per 100 pounds of fish. The drug was mixed thoroughly

with all food except that given to the controls. Trials in 1946 were limited to brook and rainbow trout. In 1947, trials were run also on brown trout.

The fish selected for this experiment were believed to be vigorous and free from disease. Unfortunately, furunculosis appeared in various lots and became serious in one lot of untreated brook trout. Mortality from this source, as in earlier experiments, increased the growth rate by making more food available to the survivors. There was also considerable mortality among brown trout and rainbow trout, but bacteriological examination showed that few rainbow trout had furunculosis. In addition to the observation of growth rates and general effects of the drug, red cell counts and hemoglobin determinations were made on brown trout in 1947.

Treatment of Brook and Rainbow Trout

Sixteen upper troughs were grouped into blocks of eight. In each block, four troughs contained rainbow and four troughs brook trout. Within each block, assignment of species to troughs, and of each of the four treatment rates to troughs, was by random selection. The fish in each trough were considered as one lot. Lots were weighed on August 8; treatment was begun on August 9 and continued for 45 days until September 23. All fish were reweighed and allotments of food and drug adjusted on the 10th, 18th, 26th and 41st days after the treatment was begun.

The daily dosage rates tried were 0 (controls), 5, 10, and 15 grams of sulfamerazine per 100 pounds of fish or 0, 11, 22 and 33 grams per 100 kilograms.

Growth rate was determined from the average weight per fish at the end of each interval (Fig. 1, Table 1). While even the heaviest dosage rate did not appreciably effect the growth of rainbow trout, growth of brook trout was retarded.

Growth of brook trout treated at the 5-gram rate was only slightly less than that of the controls which suffered moderate mortality from furunculosis[1] (Fig. 1 and Table 1). Growth was considerably reduced by the 10-gram dosage rate and still more by the 15-gram rate.

Aside from the loss caused by furunculosis among the fish not given sulfamerazine, mortality was generally light. Among the fish treated at the highest rate, one lot suffered considerable loss (5.2 percent—see Table 2). Furunculosis in this lot was not indicated by external appearance or bacteriological check of three dead fish and no mortality occurred after the 31st day. If mortality had been due to sulfamerazine poisoning, the death rate should have increased toward the end of the trial. Moreover, in the other lot treated at the highest rate, mortality (one fish) was as low as in any lot. Death rate among the fish treated at the 10-gram

[1] In one of the control tanks there was heavy mortality (74 fish or 42.3 percent). As previously noted in such cases, this meant more food and faster growth for the survivors and left only one control of value for growth comparisons. It is considered necessary in such experiments to adjust the amounts of food for all lots at the same time. Reweighing and adjustment of daily rations were done as frequently as was practical under the circumstances.

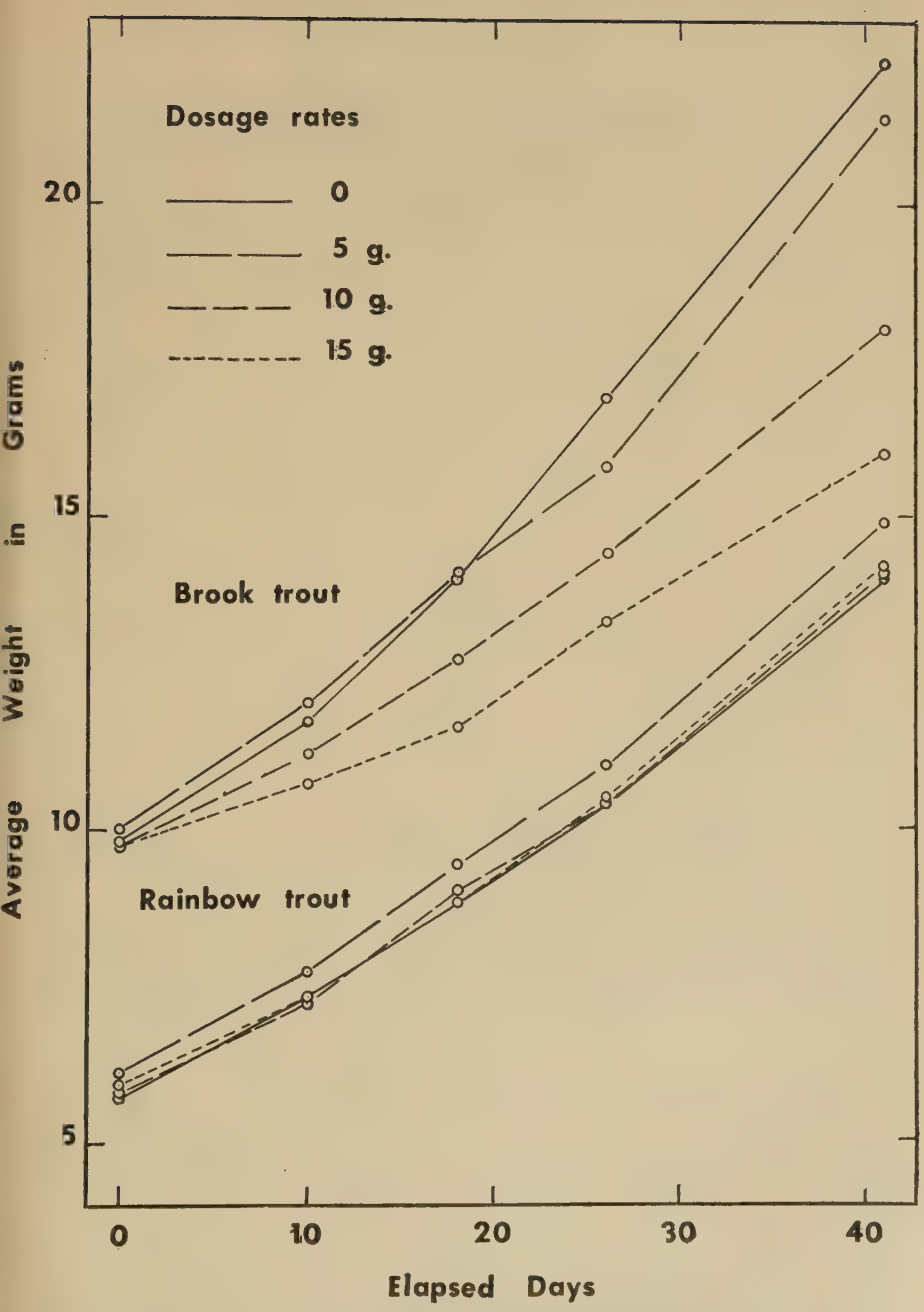

FIGURE 1.—Growth of brook and rainbow trout treated with sulfamerazine at various dosage rates (0, 5 grams, 10 grams, and 15 grams of sulfamerazine per day per 100 pounds of fish). Each point (circle) on the graph represents the average weight of the fish in two troughs.

TABLE 1.—*Average weights of fish (grams) of three species of trout treated with sulfamerazine at various dosage rates at successive intervals*

[Each average is based on the combination of data from two blocks of experimental troughs. The numbers of fish ranged from 200 to 300 per trough]

Elapsed days	Dosage rate (grams of sulfamerazine per 100 pounds of fish)			
	0	5	10	15
Brook trout (1946)				
0	9.8	10.0	9.7	9.7
11	11.7	12.0	11.2	10.7
19	14.0	14.1	12.7	11.6
27	16.9	15.8	14.4	13.3
42	22.3	21.4	18.0	16.0
Rainbow trout (1946)				
0	5.7	6.1	5.8	5.9
11	7.3	7.7	7.2	7.3
19	8.8	9.4	9.0	8.8
27	10.4	11.0	10.4	10.5
42	14.0	14.9	14.1	14.2
Brown trout (1947)				
0	9.4	8.9	8.5	8.3
15	11.1	9.1	8.2	7.9
31	12.8	9.0	8.4	7.8
51	15.4	8.8	8.0	7.6

rate was low (one fish in one lot, two fish in the other lot). Rainbow trout showed considerable scattered mortality (Table 2) not bearing any relation to the dosage rate of sulfamerazine.

Treatment at the 10-gram rate was resumed for 165 brook trout and 330 rainbow trout 1½ days after the close of the 42-day test period. Treatment was again stopped after 8½ days, and the fish were kept under observation for 5 more days. There were two deaths among the brook trout and none among the rainbows (see Gutsell and Snieszko, 1949).

TREATMENT OF BROWN TROUT

In the experiments with brown trout eight adjacent upper troughs were used. The daily dosage rates were 0, 5, 10, and 15 grams of sulfamerazine per 100 pounds of fish (or 0, 11, 22, and 33 grams per 100 kilograms). Each rate, including the 0-rate or control, was used in two troughs. Assignment of treatment to troughs was by random selection.

On August 12, 5 pounds of fingerlings were weighed and placed in each trough. Feeding and treatment were begun on August 12 and continued for 49 days until October 1. Each lot was weighed and rations were recalculated after 14 days and again after 30 days of treatment. The final weighing was on October 2, one day after final treatment.

TABLE 2.—*Mortalities (number of fish) of trout treated with sulfamerazine at various dosage rates*

[The designations B1 and B2, identify blocks of experimental troughs; A and B, replicate troughs not grouped in blocks]

Elapsed days of treatment	Dosage rate (grams of sulfamerazine per 100 pounds of fish)							
	0		5		10		15	
Brook trout								
	B1	B2	B1	B2	B1	B2	B1	B2
0– 6	0	2	2	0	0	0	0	0
7–11	0	9	0	0	0	0	1	0
12–16	4	6	0	0	0	1	5	1
17–21	4	16	2	0	0	0	2	0
22–26	7	15	1	0	0	0	1	0
27–31	4	15	1	0	0	0	2	0
32–36	6	8	0	0	0	0	0	0
37–41	1	3	0	0	1	1	0	0
42–45	2	0	0	1	0	0	0	0
Total number...	28	74	6	1	1	2	11	1
Percentage.....	13.2	42.3	3.0	0.5	0.5	1.1	5.2	0.6
Rainbow trout								
	B1	B2	B1	B2	B1	B2	B1	B2
0– 6	0	0	0	0	0	1	0	0
7–11	6	1	1	0	1	0	3	3
12–16	5	3	2	2	5	2	0	1
17–21	6	4	3	7	0	2	2	4
22–26	4	3	2	1	0	5	3	5
27–31	2	6	1	9	2	2	5	5
32–36	0	1	0	4	1	6	3	4
37–41	0	0	0	0	0	3	1	2
42–45	0	3	0	1	0	1	0	0
Total number...	23	21	9	24	9	22	17	24
Percentage.....	7.2	6.0	3.0	7.5	3.0	6.1	5.3	7.3
Brown trout								
	A	B	A	B	A	B	A	B
0– 4	0	1	4	0	1	2	1	0
5– 9	0	0	3	0	2	2	3	9
10–14	2	0	1	0	7	2	5	8
15–19	0	1	1	2	2	2	3	2
20–24	1	1	4	2	1	1	1	1
25–29	8	2	1	1	1	1	0	0
30–34	4	1	1	0	3	3	4	1
35–39	2	9	5	1	0	0	2	1
40–44	6	10	3	1	0	3	2	3
45–49	5	6	4	4	4	2	5	2
Total number...	28	31	27	11	21	18	26	27
Percentage.....	12.1	12.2	10.4	4.4	7.9	6.7	9.9	9.5

Treated fish did not consume their complete ration and failed to show significant growth during the test period (Table 1, Fig. 2).

Mortality was high in all lots. Since in all groups except the controls half or more of the mortality occurred in the first half of the trial, it is believed that the deaths were not caused by sulfamerazine poisoning. If

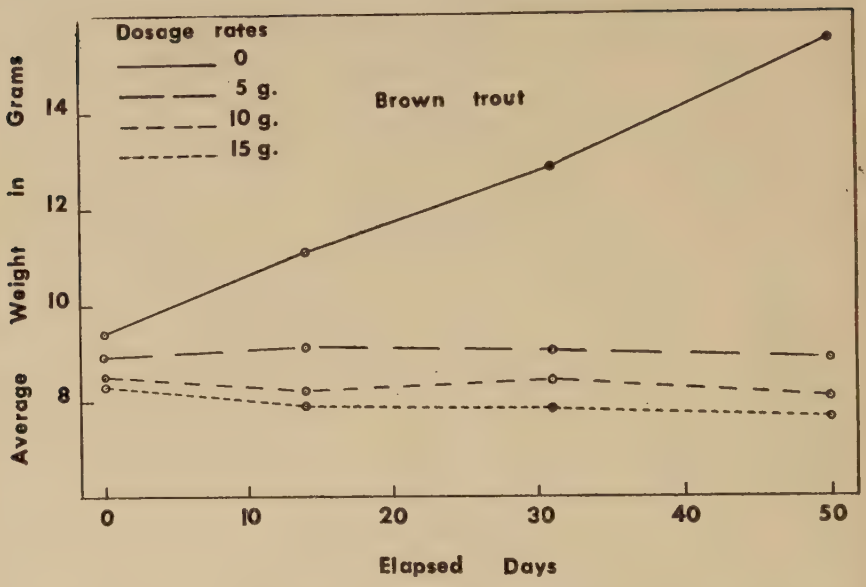

FIGURE 2.—Growth of brown trout treated with the sulfamerazine at various dosage rates (0, 5 grams, 10 grams, and 15 grams of sulfamerazine per day per 100 pounds of fish). Each point (circle) represents the average weight of the fish in two troughs.

the drug had caused the observed mortality, the rate should have continued to rise until the termination of the experiment.[2]

Of the 23 dead fish examined from the control troughs, 16 were found to have furunculosis and one was doubtful. In the lots treated with sulfamerazine, 81 dead fish examined were negative and one was doubtful.

On the day after the final weighing, three fish from each trough were examined for *Octomitus salmonis*. The parasite was abundant in 2 (8.3 percent), of the 24 fish, scarce in 4 (16.7 percent) and absent from the remaining 18.

After 36 successive days of treatment, hemoglobin was determined for 10 fish from each trough (Table 3). The mean hemoglobin content per 100 milliliters of blood was 7.0 grams for control fish; for fish treated at the 5-, 10-, and 15-gram rates the hemoglobin content was 9.7, 9.4, and 8.9 grams, respectively. Hemoglobin content was significantly higher in treated fish than in the untreated stock (analysis of variance). The level

[2] Herman (1946) following receipt of a circularized summary of Gutsell's 1945 findings used sulfamerazine effectively in the treatment of brown trout. On the twelfth day of treatment, the mortality rose from 0.16 to 0.24 percent per day, and treatment was discontinued. On the next day the mortality dropped to 0.12 percent. The decrease was taken by the investigator to indicate that the increase in the twelfth day was due to overdosage with sulfamerazine. In view of our experience, it seems improbable that his interpretation was correct.

TABLE 3.—*Hemoglobin (grams per 100 milliliters) in the blood of brown trout after 35 successive days of treatment with sulfamerazine at the daily rate of 0, 5, 10, or 15 grams per 100 pounds of fish (10 fish per trough were examined)*

[A and B represent samples from replicate troughs]

Fish number	Dosage rate (grams of sulfamerazine per 100 pounds of fish)							
	0		5		10		15	
	A	B	A	B	A	B	A	B
1	6.7	7.0	9.9	9.9	10.4	9.9	9.3	11.0
2	7.8	7.8	8.4	9.6	8.1	9.6	9.3	9.3
3	5.5	6.8	10.4	10.2	10.6	10.2	7.2	11.0
4	8.4	7.0	9.3	10.4	8.7	10.4	7.8	9.0
5	7.0	7.5	10.7	11.3	10.7	11.3	9.3	8.4
6	7.8	6.5	11.9	9.1	9.1	10.9	10.2	8.4
7	8.6	5.8	7.1	9.0	8.8	8.0	8.7	6.8
8	7.4	7.1	6.4	10.6	8.1	10.2	8.6	7.2
9	5.8	6.5	8.6	11.7	7.8	6.1	9.3	8.1
10	7.0	5.5	10.6	9.6	8.0	10.7	7.2	11.0
Trough mean.....	7.2	6.8	9.3	10.1	9.0	9.7	8.7	9.0
Treatment mean.....	7.0		9.7		9.4		8.9	

of hemoglobin for fish treated at the 5-gram rate was significantly higher than that for the 15-gram rate but not higher than that for the 10-gram rate. The difference between the levels for the 10-gram and 15-gram rates was not significant.

After 42 or more successive days of treatment, erythrocyte counts were made from five fish from each trough. Two counts were made for each fish (Table 4). The mean counts per cubic millimeter were 1,009,500 in the controls, 1,441,000 for the 5-gram rate, 1,265,250 for 10-gram rate, and 1,300,000 for the 15-gram rate. The level of erythrocytes in the treated

TABLE 4.—*Red cell counts from blood samples of brown trout after 42 or more days of continuous treatment with sulfamerazine at the daily rate of 0, 5, 10, or 15 grams per 100 pounds of fish*

[5 fish per trough, 2 slides per fish]

Dosage rate	Cell count per slide		Cells per cubic millimeter of blood
	Mean	Range	
0	201.9	197.0–206.8	1,009,500
5	288.2	274.5–301.9	1,441,000
10	253.0	231.5–274.6	1,265,250
15	260.2	247.1–273.3	1,301,000

fish was significantly greater than the level in the control. Counts for the 5-gram rate were significantly higher than those for the 10-gram rate, but not significantly higher than those for the 15-gram rate. The difference between the levels for the 10- and 15-gram rates was not significant.

Comments on the Use of Sulfamerazine

Items of special interest from this experiment are: (1) absence of lethal action of sulfamerazine; (2) absence of evidence of any directly injurious effect of the drug; (3) such retardation or cessation of growth as occurred, attributable or largely attributable to reduction in consumption of food (containing the drug); (4) great variation among the three species of trout in their response to the drug (dislike or indifference); (5) increase in amount of hemoglobin and numbers of erythrocytes of brown trout with sulfamerazine in the food; (6) very small consumption of the drug, begun in time, apparently sufficient to control furunculosis in brown trout. These points will be considered in more detail in the following paragraphs.

Analysis of the data presented above indicates that observed mortalities could not be attributed to treatment with sulfamerazine. Brook trout had a low death rate even at the high dosages and light or no mortality during the latter part of the treatment. Rainbow trout and brown trout suffered considerable but scattered mortality. In the treated lots, losses were lighter toward the end of the treatment period. Where losses of brown trout were above the average, half or more of the deaths occurred during the first half of the trial.

Insofar as could be judged by hemoglobin analysis and erythrocyte counts in brown trout, the drug treatment had no injurious effects. In treated fish both were higher than in the controls. Likewise, anemia was not observed among the brook and rainbow trout. The only adverse effects observed were reduction in food consumption and reduction or cessation of growth. Where there was retardation of growth, consumption of the treated food was poor. When consumption of treated food was good, growth was equal or nearly equal to that in the controls. The apparent explanation of reduced food consumption when sulfamerazine was mixed with the food, is that certain species of trout dislike the taste of the drug. It was noted that early in the trials trout rushed to the treated food, took it into their mouths, and then ejected it. Growth of rainbow trout did not appear to be affected and brook trout showed marked retardation of growth only at the 10- and 15-gram dosage rates. On the other hand, food consumption was very poor and growth stopped in brown trout treated with sulfamerazine at any rate.

The increase of hemoglobin and of erythrocytes in fish treated with sulfamerazine may have several explanations. It is possible that some infection causing a moderate anemia,[3] was cured or greatly reduced by sulfamerazine therapy. Another hypothesis is based on the finding (Altman, 1946) that sulfonamides inhibit the respiratory enzymes. It seems possible that this action has the same effect as a reduction in the supply of oxygen and like it results in higher erythrocyte and hemoglobin levels (Phillips *et al.*, 1946). A final possibility is that sulmamerazine actually stimulated the production of hemoglobin and erythrocytes.

[3] Apparently furunculosis does not have this effect. Field *et al.* (1944) found that the red cell counts and hemoglobin of carp inoculated with *B. salmonicida* were essentially the same as in the control animals.

The high percentage (73.0 percent) of untreated dead brown trout which had furunculosis and absence of the disease in the treated fish indicated that good control was effected when treatment was started before the disease appeared in the untreated lots. Since the treated fish actually consumed very little sulfamerazine, it appears that treatment at a very low rate, if begun in time, is sufficient to control furunculosis in brown trout. This fact is important because brown trout apparently can be treated only at a low rate. Possibly a higher rate of food consumption together with growth can be attained with a concentration of the drug much lower than that used for brook trout. Brief alternate periods of treatment and non-treatment might also prove better for brown trout than continuous treatment.

In view of the marked dissimilarity in response to sulfamerazine of the three salmonid species, it is important that the response of other important species such as lake trout, cutthroat trout, and Atlantic salmon be tested.

Acknowledgements

The authors wish to thank Dr. C. M. Mottley for helpful suggestions and advice, particularly in regard to the analysis of the data as to erythrocytes and hemoglobin blood levels in brown trout, and Messrs. E. W. Surber and B. H. Hazen for the use of hatchery troughs and for many other courtesies. Mr. Saufley B. Friddle cooperated in the work in 1947, with brown trout.

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CYTOPHAGA COLUMNARIS AS A CAUSE OF FISH EPIDEMICS

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Abstract

An epidemic, resulting in the death of large numbers of white crappies (*Pomoxis annularis*) in McKay Reservoir near Pendleton, Oregon, was found to be due to infection with *Cytophaga columnaris,* a myxobacterium. Extensive lesions produced by this organism were present on the body and gills of dead and dying fish. Since other epidemics are known to have been produced by *C. columnaris,* it is suggested that during warm weather this organism may be a frequent cause of mortalities among fish in lakes and possibly in streams.

The prevalence of disease among fish in natural waters has received little attention in this country and there is a general belief that epidemics caused by infectious diseases are very exceptional under such conditions. Although heavy mortalities are reported occasionally, they are usually blamed on pollution and oxygen deficiency. Those factors are, no doubt, a frequent cause of fish mortality but the possibility of the presence of an infectious disease should by no means be ignored.

The writer has recently had an opportunity to investigate a heavy mortality among white crappies (*Pomoxis annularis*) in McKay Reservoir near Pendleton, Oregon. This artificial reservoir, which has an area of over 1,600 acres, is used for storing water for irrigation and has been in operation for a number of years. Fish were reported dying early in June, and at the time of the writer's visit on June 11, 1947, thousands of dead crappies lined the shore. Dead and dying fish were also found floating on the surface in parts of the reservoir known to be frequented by crappies. All crappies observed were either dead or dying and it was evident that they came to the surface only when in the last stages of the disease.

All fish showed the characteristic lesions produced by *Cytophaga columnaris,* one of the myxobacteria, which was evidently the cause of the mortality. This organism was first described by the writer (Davis, 1922) as the cause of serious mortalities among fishes from the Mississippi River. It is known to infect many species of fresh-water fishes although some are more susceptible than others. The bacteria live on the surface of the body, fins, and gills, producing extensive lesions which eventually cause the death of the fish. Recently the bacteria have been grown in pure culture by Garnjobst (1945) who has published a detailed description of the organism and its cultural characteristics.

The disease is definitely a hot-weather ailment since the bacteria multiply rapidly only at comparatively high temperatures. Garnjobst found

the optimum temperature to be 77° to 88° F. and though the organism will grow at considerably lower temperatures, it is not ordinarily injurious at temperatures below 65° to 70° F. During hot weather the disease is very likely to appear within a day or two after fish have been handled, and apparently even a very slight injury may result in infection. It may also break out among fish in small, shallow pools rich in organic matter when the water becomes unusually warm and stagnant. It is now evident that the disease is more common than has been realized and that it may cause destructive epidemics in large bodies of water, even when living conditions are not particularly unfavorable.

Although temperatures in McKay Reservoir during the epidemic are unknown, it is probable that they were high. The latter part of May was notable for exceptionally hot weather and water temperatures on June 1, when fish were first seen dying in large numbers, were probably well above 70° F. At the time of the writer's visit on June 11, surface temperatures of the water ranged from 70° to 74° F. but this was following several days of rain and cooler weather.

The fish showed lesions on the body, fins, and gills, but since all were in late stages of the disease, it was impossible in most cases to determine where the infection first appeared. It was evident, however, that it did not always start in the same place. On most fish it appeared that the gills or caudal fin were infected first but there were numerous exceptions. Frequently lesions were present on one side of the fish only. On several crappies the lesions were confined to the gills and in nearly all cases, the gills became infected before the fish died, even when it was evident that the infection had started elsewhere.

No information was obtained that would throw light on the means by which the fish became infected. There was no evidence that they had been injured and no parasites were found on the body or fins. A few trichodinids and gyrodactylid worms were sometimes present on the gills, but they were so few that it is doubtful whether they were a factor in spreading the disease. Neither was there any reason to believe that the vitality of the fish had been lowered by excessively high temperatures or by oxygen deficiency, although the oxygen content of the water was not determined. The lake had just begun to recede from its maximum level and fish were dying in open waters as well as in the more enclosed and shallower areas along shore.

Apparently only crappies were infected. Largemouth black bass, yellow perch, suckers, carp, and catfish are known to be present in considerable numbers but there was no indication of any abnormal mortality among them. Dead carp, catfish, and sucker (one of each) were observed but all had decomposed so badly that it was impossible to determine the cause of death.

Several previous epidemics are reported to have occurred among white crappies in McKay Reservoir—the last one in 1945. They all broke out at about the same time of the year and never later in the season when

water conditions are said to be much worse. A similar mortality among white crappies is reported to have occurred in Owyhee Reservoir during June 1946, but no investigation was made at the time. Owyhee Reservoir is located in southeastern Oregon but is much larger than McKay and has been completed only recently.

An epidemic among white crappies also occurred in Coolidge Lake, Arizona, in 1942. During August of that year fish were reported to be dying by the thousands and specimens of diseased fish sent to the writer were found to be heavily infected with *C. columnaris*. In this epidemic also, it was reported that only white crappies were affected.

It is evident from the information at hand that *C. columnaris* may cause serious epidemics among white crappies under certain conditions. Whether these epidemics occur only in lakes and are confined to the white crappie, it is impossible to say. There are reports of epidemics in streams and among other species of fish which might very well have been caused by *C. columnaris*. It should be pointed out, moreover, that reports that only white crappies were affected in the epidemics just described may be misleading. Conditions in these impoundments are well suited to the white crappie which multiplies rapidly and frequently becomes the most abundant fish. In fact, the epidemic may have been the direct result of the excessive numbers of these fish which are known to be very susceptible to infection with *C. columnaris*. Infection in other species, which are less susceptible and less abundant, might easily be overlooked since the crappies would naturally be the center of attention.

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LAKE-MANAGEMENT STUDIES IN OREGON [1]

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Abstract

This paper presents the results of creel censuses being carried out on four major lakes in Oregon's Cascade Mountains. The study on one lake commenced in 1945 and on the other three in 1946. The fish population of one of the lakes, 130 acres in area, was removed by poison in 1941; all plantings of rainbow trout (*Salmo gairdnerii*) since that time can be identified in the catch. Two of the lakes of approximately 1,000 acres each are stocked annually with rainbow and eastern brook trout (*Salvelinus fontinalis*) and the fourth of approximately 3,000 acres is stocked annually with rainbow trout fry produced from an egg-taking station at the lake.

The primary objectives of the creel-census studies are to determine proper stocking policies and other management techniques to meet the great increase in fishing pressure not only on these but on many similar waters.

Significant disclosures thus far include a decrease in average size of fish taken that is attributable to the heavy fishing pressure and in one lake in particular, to the presence of a large population of Klamath chub (*Siphateles bicolor*) which are competing for the available food supply. Data are at hand which illustrate the poor results in terms of survival from fall plants of fingerlings 3 to 4 inches long as compared to spring plants of fish 5 to 7 inches long. Another disclosure of interest is the sharp drop that occurs in the take of spring-planted fish the year following planting.

Introduction

Oregon has at the present time on public lands approximately 1,000 fresh-water lakes and reservoirs ranging in size from small ponds of an acre or less to lakes of 5,000 and more acres. The majority of these waters are situated in the Cascade Mountains, a range which divides the state from north to south into a temperate, comparatively wet western portion and a dry eastern portion. The lakes are found from sea level up to elevations of over 8,000 feet.

Prior to 1940 the Oregon Game Commission had only a small amount of information concerning the majority of these bodies of water. That year a crew was put in the field to survey lakes in the most important fishing area in the state—that lying within the Deschutes National Forest on the east slope of the Cascades. In 1941 and again in 1946 further surveys were made in this area and in the eastern part of the state. Most of the lake-

[1] Most of the data used in preparation of this paper were collected by field agents of the Oregon State Game Commission, including H. R. Newcomb, Braden Pillow, J. B. Dimick, R. L. Borovicka, F. E. Locke, and Allen Lichens. The work was under the supervision of Dr. P. R. Needham with the assistance of the writer.

management work, except for rough-fish control, has been undertaken in the last 2 years.

The original surveys uncovered many problems inherent in lake management. These investigations also provided certain basic information which has been useful from an administrative standpoint. It was apparent, however, that surveys were not of particular value unless periodic rechecks were made. Some recheck surveys have been made but the main activity in the last 2 or 3 years has been directed towards rough-fish control, creel-census investigations, and population studies. Each of these activities is important in the over-all management program. This paper is concerned only with creel-census investigations.

Creel-Census Investigations

This investigational procedure has been utilized rather extensively by the Oregon Game Commission over a period of several years, but most work along this line has been accomplished within the last 3 years. The primary objectives of these studies are to ascertain the catch from the lakes, to establish trends, and to determine the most satisfactory stocking and other management procedures to insure a continuing supply of fish.

At one time the Game Commission attempted to obtain catch records through voluntary participation of the anglers, but this procedure was not successful. At present we are carrying on four lake-management studies in which a creel census is utilized. These four lakes are among the most important trout lakes in the state, and all of them are very heavily fished. They are all found in the heart of the main lake fishing area of the state, in or near the Cascade Mountains.

South Twin Lake.—This lake with an area of 130 acres and lying at an elevation of approximately 4,000 feet is situated in the Deschutes National Forest on the east side of the Cascade Mountains. It is exceptionally productive. There are no visible inlets or outlet. The lake is readily accessible by road from the city of Bend about 40 miles distant.

When South Twin Lake was surveyed in 1940 it was found to be heavily infested with Klamath chub. Complete poisoning was accomplished in April 1941 at which time an estimated 35 tons of Klamath chubs were killed and only 7 game fish were found. This situation existed in a lake which but a few years previously had produced excellent trout fishing. It was decided to establish the lake as an experimental body of water, primarily to determine growth rates, total productivity, and survival from year to year of various sizes of rainbow trout planted in the fall and in the spring. Since the first planting was made in 1942 the lake has been stocked annually with the exception of 1945. The fish of all plantings except those made the first 3 years have been marked by fin-clipping for later identification. The lake was not opened to fishing until the summer of 1945 when a 2-month season extended from May 30 through July 31. The creel census, started in 1945, has been carried on each season since the lake was opened to fishing.

The bag limit on this lake is 5 fish per day with a minimum length limit of 6 inches. Table 1 shows the plantings that have been made in the lake since 1942 and the total catch for each of the past 3 years. Table 2 gives the return to the creel of the plantings made up through the spring of 1947.

A total of 114,044 fish with a gross weight of 5,396 pounds have been planted in this lake since 1942, excluding this spring's plant completed on May 12. In 6 months of fishing from 1945 through 1947, 27,882 fish weighing 23,251 pounds have been taken.

The 1946 fall plant of 5,032 fish 3.75 inches long contributed only a "drop in the bucket" to the 1947 catch. Possibly more of these fish will show up in the 1948 catch. At any rate the evidence is insufficient to condemn fall plantings completely in such lakes. Further evidence will be obtained to substantiate or invalidate the present assumption that fall plants are undesirable. Over 60 percent of the rainbow trout of the 1946 spring plant have been caught and over 49 percent of the 1947 plant were taken in 1947. An over-all survival to the creel of 24.4 percent of planted fish has been obtained thus far. There is, of course, a marked drop the second year in returns from a planting made in the spring of the previous year. The spring-planted fish have been placed in the lake as early as it is accessible.

Table 3 gives a comparison of the catch statistics for the past 3 seasons

TABLE 1.—*Details concerning plantings of rainbow trout in South Twin Lake*

Year	Number of fish planted	Weight (pounds)	Length (inches)	Fins clipped	Time of plant	Number of fish caught	Average weight of fish
1942	34,820	887	4	None	Fall	Closed	....
1943	35,000	175	2	do.	do.	do.	....
1944	10,375	125	3	do.	do.	do.	....
1945	.....	.....	.....	.....	.....	9,365	1.03
1946	15,760	2,569	3–18	Adipose	Spring	10,043	0.65
1946	5,032	68	3.75	Adipose and right pelvic	Fall	262	....
1947	13,057	1,572	6–7	Left pelvic	Spring	8,444	0.83
1948	26,000	5,720	8–8.5	Right pelvic	do.	.....	....

on South Twin Lake. It can be seen that the angling pressure and the time required to catch a fish both have increased each year. The average catch has declined from 2.9 to 1.5 fish per angler, and the average weight has also shown a decided decrease. In short, the angling pressure is so great that many of the fish are being removed before they have had an opportunity to make much growth. Nearly 80 percent of last year's catch was made up of trout planted in the fall of 1946 and the spring of 1947.

In 1945, examination of the fish disclosed a high percentage of ripe females. A month's delay in the opening of the angling season since that time has practically eliminated ripe fish from the catch.

This spring the lake was "saturated" with 26,000 rainbow trout weighing 5,726 pounds, and averaging over 8 inches long. This planting will, of

TABLE 2.—*Number and percentage of rainbow trout recaptured of each planting in South Twin Lake in each year*[1]

Year	Time of plant	Number of fish planted	Numbers and percentage returned each year						Total number	Percentage
			1945		1946		1947			
			Number	Percentage	Number	Percentage	Number	Percentage		
1942–44	Fall	80,195	9,365	11.7	1,862	2.3	350	.4	11,577	14.4
1946	Spring	15,760	.....	....	8,181	51.9	1,385	8.8	9,566	60.1
1946	Fall	5,032	.....	....	.....	....	262	5.2	262	5.2
1947	Spring	13,057	.....	....	.....	....	6,447	49.3	6,477	49.3
Totals	.....	114,044	9,365	....	10,043	....	8,444	....	27,882	....

[1] Returns from 1948, spring plant of 26,000 rainbow were not available when this paper was prepared

TABLE 3.—*Comparison of results from creel-census studies on South Twin Lake, 1945–1947*
[The open season is given in parentheses for each year]

Item	1945 (May 30–July 31)	1946 (June 29–August 31)	1947 (June 28–August 24)
Number of angler trips	3,149	4,729	5,392
Number of fish examined	9,365	10,043	8,444
Total weight (pounds)	9,694	6,537	7,020
Average weight (pounds)	1.03	0.65	0.83
Catch per surface acre (pounds)	74.6	50.7	54.0
Man-hours of fishing	11,989	21,640	25,549
Average catch of fish	2.9	2.1	1.5
Hours per fish	1.28	2.15	3.00
Fish per hour	0.78	0.46	0.33
Range in length (inches)	7–18	6–18	7–21.5

course, invite a terrific angling pressure on the lake, but it is hoped that the catch per angler will rise in proportion to the increased stocking. The season will open on June 15 and will end on August 15.

Within reasonable limits it is fairly easy to predict how many fish will be taken from South Twin Lake this year and the percentage representation of each plant. This fact alone is important in determining the future course of events in this lake. Continuation of the project should disclose the most economical stocking policy for receiving the maximum return to the creel.

East and Paulina Lakes.—Lying but a short distance apart in the crater of an extinct volcano southeast of Bend in central Oregon are without question two of the most important trout lakes in the entire state. East Lake lies slightly above Paulina at an elevation of 6,378 feet. It has an area of 970 acres and no visible inlets or outlet; approximately 65 percent of the lake is less than 50 feet deep. Paulina Lake has an area of 1,300 acres, is without visible inlets, but has a screened outlet; only 25 percent of the lake is under 50 feet in depth. East Lake is by far the more productive of the two lakes because of the larger area of shoal water. Both lakes are easily accessible by road and have resorts and camping accommodations.

The two lakes were surveyed thoroughly in 1940, and re-examinations, consisting mainly of population studies, were made in 1941 and 1946. At the present time both lakes contain rainbow, eastern brook, and brown trout (*Salmo trutta*). The last introduction of brown trout was made in 1939; since that time only rainbow and eastern brook trout have been planted. Klamath chubs are present in both lakes, with the heavier concentration in East Lake. Partial control measures carried out annually since 1941 have kept their numbers down. An effort was made to determine the harvest from these lakes by means of voluntary catch records but this procedure proved unsuccessful. Because of the increasing pressure on the lakes, the apparent decline in fishing, and their importance from a recreational standpoint, the Game Commission decided to inaugurate a creel-census study so that an intelligent management program could be devised. This creel census was started in 1946, and it is proposed that it

continue for a period of at least 5 years. Data have been obtained by contacting anglers at boat docks, on the lakes, and in the campgrounds. It has been impossible to make a 100-percent check, but the 70-percent sample obtained is considered adequate for the accurate estimation of the total catch. Signs, printed material, and newspaper publicity have served to acquaint the anglers with the project and the purpose behind it.

Tables 4 and 5 show the plantings made in each of these lakes since

TABLE 4.—*Details concerning plantings of rainbow trout and eastern brook trout in East Lake, 1942–1947*

Year	Rainbow trout			Eastern brook trout		
	Number of fish planted	Average length (inches)	Time of plant	Number of fish planted	Average length (inches)	Time of plant
1942	340,914	4.5	.....	465,307	4.5	.....
1943	432,860	2.5	.....	481,030	2.25	.....
1944	72,000	2.0	.....	413,085	2	.....
1945	None	.....	.....	600,210	1.5	.....
1946	230,280	Fry	June	15,770	4	June
do.	11,978	2–2.5	do.	33,840	2.25	July
do.	39,438	3–3.5	October	[1]49,610	.....	.....
do.	[1]281,696	.....	.....	.....	.....	.....
1947	822,500	Fry	July	100,000	Fry	Spring
do.	7,620	6	May	104,695	2–4	do.
do.	24,050	5.5	do.	7,500	4–6	do.
do.	[2]854,170	.....	.....	6,300	6	do.
do.	.....	.....	.....	2,200	8–9	Fall
do.	.....	.....	.....	[2]220,695	.....	.....

[1] Total for 1946
[2] Total for 1947

1942, and Table 6 summarizes the catch statistics from both lakes for the 1946 and 1947 seasons.

In 1939 a partial creel census conducted by the resort owner at Paulina Lake yielded an estimate of 21,126 fish taken by 1,612 anglers, giving a figure of 12.09 fish per angler or 12 times the success ratio obtained in that lake in 1946 by approximately 5 times as many anglers. Much the same is true at East Lake although no comparative figures are available. From 1939 to 1947 the angling pressure on Paulina Lake increased over 600 percent. The pressure on East Lake increased over 400 percent in the same period.

In 1947 nearly 75 percent of the trout taken from East Lake and over 80 percent of those caught from Paulina were under 3 years old. This low age indicates a high rate of removal of fish planted in 1946 and the spring of 1947. The decrease in average size in both lakes is the result of the increased fishing intensity and larger take of young fish.

With both lakes it is desirable to determine a stocking program that

TABLE 5.—*Details concerning plantings of rainbow trout and eastern brook trout in Paulina Lake, 1942–1947*

Year	Rainbow trout			Eastern brook trout		
	Number of fish planted	Average length (inches)	Time of plant	Number of fish planted	Average length (inches)	Time of plant
1942	195,281	4.5	.....	569,327	4.5	.....
1943	324,225	2.5	.....	493,070	2.5	.....
1944	188,880	2.5	.....	446,842	2.5	.....
1945	392,968	1.5	.....	392,968	2	.....
1946	19,059	2–2.5	June	42,620	4–4.5	June
do.	311,284	Fry	June, July	23,088	2	July
do.	56,643	3–3.5	October	64,180	5–6	October
do.	[1]386,986	.....	.....	[1]129,888	.....	.....
1947	20,800	7	May	99,940	1.75	May
do.	10,500	5.5	do.	25,000	3.75–4.5	do.
do.	157,650	3.5–4	October	77,995	3–3.5	October
do.	[2]188,950	.....	.....	21,052	2–2.5	do.
do.	.....	.....	.....	9,150	8–9	do.
do.	.....	.....	.....	[2]233,137	.....	.....

[1] Totals for 1946
[2] Totals for 1947

will provide a higher return to each angler in spite of an expected continued increase in angling pressure. Whether this end can be accomplished most economically by planting fry, fingerlings, or legal-sized fish remains to be seen. Perhaps further restrictions will be necessary on seasons and bag limits. During the war years both lakes were understocked, and that fact has certainly affected the fishing recently. As with South Twin Lake the picture is one of continually increasing pressure and an overcropping of the younger age groups.

Diamond Lake.—This lake of 2,900 acres lies at an elevation of approximately 1 mile in the Cascade Mountains. It has long been considered the finest rainbow trout lake in the state. Until a few years ago trout weighing 8 to 10 pounds were common in the catch. The lake has several inlets which are not particularly suitable for spawning. Stocking is

TABLE 6.—*Comparison of 1946 and 1947 catch statistics for East and Paulina Lakes*

Item	East Lake		Paulina Lake	
	1947	1946	1946	1947
Number of fish	12,933	17,390	7,269	19,646
Number of anglers	14,084	14,720	7,692	10,743
Fish per angler	0.99	1.18	1.01	1.8
Total pounds	23,123	20,610	8,070	12,496
Hours per fish	5.0	4.7	5.2	2.5
Percentage of rainbow trout	49	48.5	36.3	53
Percentage of eastern brook trout	46	49.7	49.5	42.7
Percentage of brown trout	5	1.8	15.2	4.3
Average weight (pounds)	1.75	1.18	1.12	0.63

maintained through the operation of an egg-taking station at the outlet. At the present time, there are three species of fish in the lake, rainbow trout, brown trout, and Klamath chub. The brown trout entered Diamond Lake from a planting made in a small tributary lake. The Klamath chub was introduced by careless fishermen and is extremely abundant at the present time. Table 7 shows the plantings made in this lake since 1938. All fish are planted as soon as they have absorbed the yolk sac. Table 8 compares the catch statistics for 1946 and 1947.

It is shown that the total number of anglers and the total catch increased tremendously from 1946 to 1947. At the same time the average weight and size of the fish taken decreased considerably, indicating a situation parallel to that existing on the three lakes discussed previously.

TABLE 7.—*Number of rainbow trout fry planted in Diamond Lake, 1938–1947*

Year	Number of fry	Year	Number of fry
1938	1,285,000	1943	880,740
1939	1,957,300	1944	2,280,960
1940	2,014,597	1945	2,583,800
1941	2,256,200	1946	3,689,256
1942	2,178,720	1947	3,340,305

Most of the fish taken are 3 years old; they are not being left in the lake long enough to reach a greater age. The small take in 1946 is attributable to the poor brood year of 1943 when only 880,740 young were planted.

The brood stock at Diamond Lake is being depleted because of the excessive fishing. In 1948 the weekly possession limit was reduced to 10 fish, and the season was set back to reduce the early-season catch and to allow the spawning fish time to move off the shoal areas. A minimum length limit of 10 inches has been in effect for several years. These re-

TABLE 8.—*Comparison of 1946 and 1947 catch statistics for Diamond Lake*

Item	1946	1947
Number of fish	12,800	37,500
Number of anglers	14,800	26,800
Fish per angler	0.86	1.40
Total pounds	24,320	45,000
Hours per pound	0.19	0.33
Average weight (pounds)	1.9	1.2
Average length (inches)	15.75	13.75

strictions and changes may not be sufficient to halt the present trend, but they should help.

Present plans call for stocking the lake at the rate of 1,000 fry per acre, maintaining the creel-census, and continuing to control the Klamath chub.

The trends indicated in the lakes discussed in the preceding pages are undoubtedly typical of those existing in many accessible trout lakes in Oregon. Evidence to support this assumption comes from partial creel censuses made in other areas of the state. It seems likely that further restrictions will be necessary if the present upswing in angling pressure continues. Fertilization, although expensive, may prove profitable on some lakes to increase the yield. On others, which have "trash" and other undesirable fish, the answer may lie only in complete poisoning of the stock and a fresh start. One method of reducing the pressure on overfished lakes is to increase the yield in other bodies of water that are not producing to capacity at the present time.

Along with the projects outlined above, several cooperative creel-census investigations are under way. Tagged fish invariably are planted in cooperative work because they may be recognized easily when they are caught. It is hoped that this phase of the program can be expanded through greater participation by sportsmen and resort owners. On the most important lakes, at least, a creel census is essential to intelligent management.

MORTALITY RATES IN SOME LITTLE-EXPLOITED POPULATIONS OF FRESH-WATER FISHES [1]

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ABSTRACT

Mortality and survival in four little-exploited fish populations which have been studied by Hart, Hile, and Kennedy are estimated by comparison of the number of individuals of successive ages taken by gill nets. The selectivity of gill nets makes it possible to use only the older fish in their catch for this purpose. For the whitefish of Shakespeare Island Lake in Lake Nipigon, it is possible to demonstrate that a length of 13 inches is the boundary beyond which the effects of selection become inappreciable. In this population mortality rate is very low, varying from 8 percent at age-group XII to 17 percent at XX, and up to 45 percent at XXVII. In Lake Nipigon itself the whitefish died at the rate of 36 percent per year between age-groups XIII and XX; these larger figures presumably were chiefly or entirely the result of commercial fishing. Whitefish of Lake Opeongo died off much more rapidly than either of those cited above, even without fishing, the mortality varying from 41 percent for age-group VII to 59 percent at XIII. The unexploited sauger of Lake Nipigon had mortality rates varying from 26 percent for age-group X to 60 percent for age-group XIV. The oldest of the rock bass of Nebish Lake were dying off rapidly at an annual rate of 66 percent (age-group XI) to 79 percent (age-group XIV). Male rock bass died more rapidly than did females of the same age. In all these unexploited populations mortality rate increased steadily with age over the range in which it could be measured.

INTRODUCTION

The age distribution existing in a randomly taken sample of a fish population can be used to estimate the survival rate of the population during successive years of life. For some purposes the survival rates existing in *unexploited* populations are of exceptional interest. For one thing, the mortality rate which then obtains at successive ages can be used, in default of better information, as an estimate of the natural mortality rate at corresponding ages under conditions of exploitation. Equally important is the light which the structure of the primitive population may shed on the question of the mechanism of natural regulation or balance in the population. Unfortunately for the widespread use of this information, the study of a fish population usually begins only after a fishery has been active for a considerable number of years. Thus studies of unexploited populations are prized rarities in fishery literature.

The writer has already called attention to a primitive age distribution

[1] Contribution No. 394 from the Department of Zoology, Indiana University.

of mortality in a population of Pacific herring sampled by Dr. A. L. Tester (Ricker, 1948). The present paper is devoted to the analysis of mortality in some fresh-water populations, untouched by man or nearly so, of which accounts have been published. Such accounts for the most part deal primarily with the rate of growth of the population concerned, but in some cases it is possible to estimate survival rate from the data with at least fair accuracy. In addition to their intrinsic value, it is hoped that these examples will stimulate interest in the investigation of unexploited populations which may still exist throughout the continent. Such populations, of the valuable food and game species at least, are becoming scarcer as the years go by, and if good information concerning a number of them is not obtained soon, it may never become available.

Methods

In this study survival rates and mortality rates are estimated from age frequencies in the catch, by plotting the logarithms of frequencies against age and taking the slope of the resulting *catch curve* at successive ages (*cf.* Ricker, 1948). This procedure is affected by three principal sources of error, one systematic and two random.

Systematic error comes from the unequal vulnerability of fish of different ages to the fishing gear in use. All of the samples used here were taken by means of gill nets, a type of gear notoriously selective by size, and hence by age. Usually the nets fished were a gang of graded meshes, so that the range of sizes caught was quite wide; but this does not necessarily assure proportionate representation for all the different ages of fish present. In general, vulnerability to gill nets of a fish of any species will increase with its size (and hence, in general, with its age) up to a certain point, *even when the most efficient mesh of net is used for each size of fish.* The modal age in the catch taken by a gang of graded nets is practically always greater than age-group I, and often it is considerably greater. Obviously no information about survival rate is to be obtained from fish younger than the modal age. Beyond it, it is wise to avoid placing any great confidence in figures obtained from ages close to the mode because of the possibility of a continued significant increase in vulnerability. These regions correspond to the "ascending limb and dome" of the catch curve. Beyond this point there is usually no *direct* evidence whether vulnerability continues to increase or not. However, among older fish rate of increase in length usually declines rapidly, so that successive ages differ little in size, and under such conditions there is little continued increase in vulnerability. That is, vulnerability to gill nets is principally a function of the linear dimensions of a fish, and it is commonly observed that among old fish several adjacent ages will be taken in even a single size of gill net without any pronounced selection for size. If, then, nets of a graded series rather than of a single mesh size are used, there is a good chance that the effects of selection will be completely negligible among the older fish.

It is possible to make a direct demonstration of this point for one population, the whitefish of Shakespeare Island Lake described by Hart (1932). An attempt was made to estimate the total whitefish population of this lake by intensive netting with a gang of gill nets which included 50 yards each of sizes 1½, 2, 2¼, 2½, 2¾, 3, 3½, 4, 4½, 4¾, and 5 inches, stretched mesh. Sets were divided into 7 series, each including 5 sets at specific locations. These locations were well distributed over the lake; and since its surface area was only 81 acres, there seems little chance that any considerable number of fish were not exposed to capture. In other words, the falling off in catch which was observed is in all probability the result of an actual decrease in the total population of the lake. The simplest and most plausible relationship between catch and series number is that in each series the nets would tend to take a definite percentage of the fish available. If so, the logarithms of the numbers taken should constitute a linear series, within limits of random variation. And as a matter of fact, such a line gives the best reasonably simple fit to the data obtained. From Hart's Figure 6 the summary of Table 1 and Figure 1 is taken, showing the logarithms of the number of fish caught in successive series arranged by 2-inch intervals of length. The 9- to 10-inch class needs special mention. Owing to the almost complete absence of fish of age-group III, there was a gap in the length distribution of the population whose upper boundary was at 9 inches when netting started but had moved up about ½ inch by its close, as a result of the growth of the fish. This situation causes the apparent decrease in numbers of the 9- to 10-inch class, shown by the dotted line in Figure 1, to be greater than its actual

TABLE 1.—*Logarithms of the number of whitefish caught in each of seven successive series of sets in Shakespeare Island Lake, for seven length classes*

[The last three columns show the coefficient of regression (b) of these logarithms on series number, the standard error of the regression coefficient (sb), and the mean percentage apparent decrease in each per series (the complement of the antilogarithm of b). Fish were measured to the fork of the tail, at quarter-inch intervals; length-class 7–8 includes measurements from 7 inches to 8¾ inches, ... Data from Hart (1932)]

Length class (inches)	Series of sets							b	sb	Percentage decrease per series
	I	II	III	IV	V	VI	VII			
7– 8.....	1.26	1.43	1.28	1.32	1.26	1.11	1.23	−.0268	0.0159	6.0
9–10.....	1.76	1.71	1.51	1.30	1.48	1.34	1.15	−.0928	0.0190	19.3
11–12.....	1.59	1.64	1.36	1.11	1.43	1.36	1.30	−.0486	0.0300	10.6
13–14.....	1.40	1.42	1.18	1.11	1.08	1.11	0.70	−.1007	0.0211	20.7
15–16.....	1.49	1.52	1.30	1.18	0.85	1.00	1.08	−.0971	0.0180	20.0
17–18.....	1.49	1.36	0.85	1.18	0.78	1.00	0.60	−.1236	0.0381	24.8
19–20.....	0.90	0.70	0.30	0.30	0.30	0.48	0.30	−.0800	0.0352	16.8

decrease, which can be estimated only by interpolation (solid line in Figure 1). The 7- to 8-inch class is not similarly affected because it included practically all the II-group fish, and no others, throughout the whole time of netting. Allowing for the above exception, it will be ob-

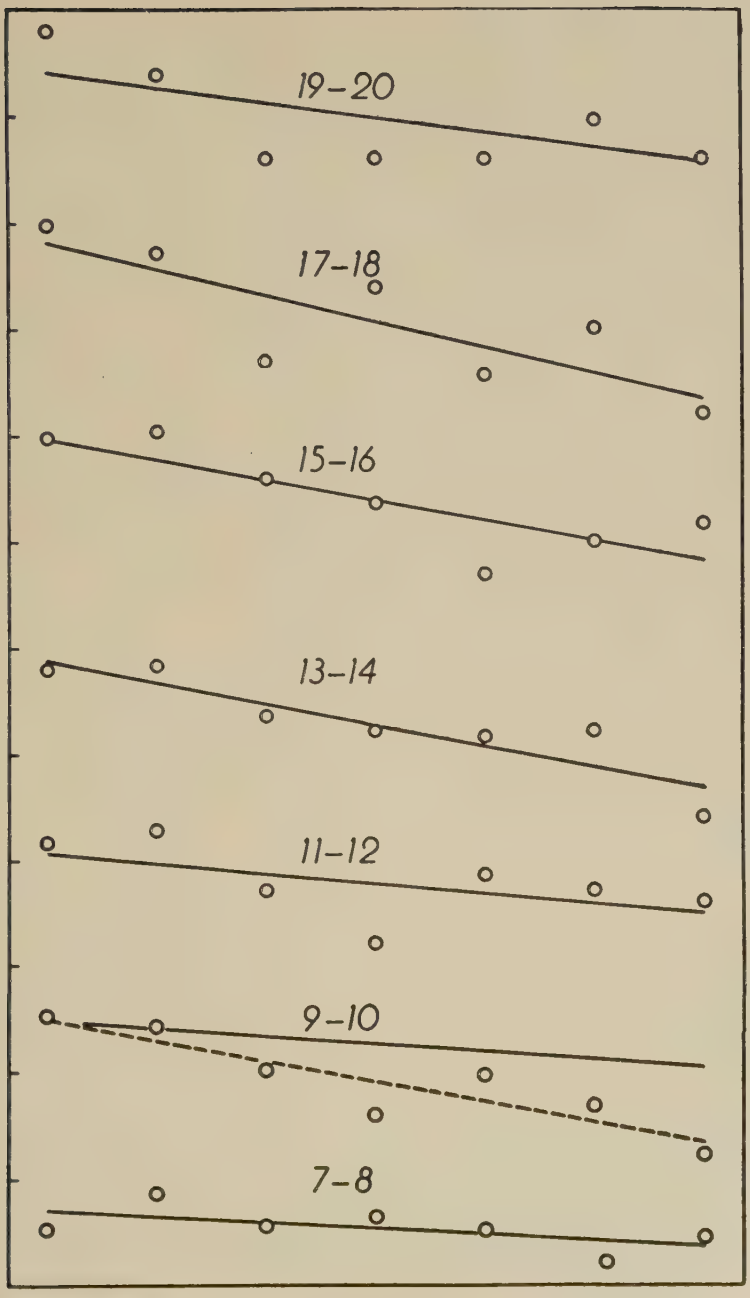

FIGURE 1. Logarithms of the catch of Shakespeare Island Lake whitefish in 7 successive series of gill-net sets, arranged in length-classes 2 inches broad (data from Hart, 1932). Each ordinate division is 0.5 log unit.

served that the negative regression of the logarithm of frequency on time increases as the size of the fish increases, up to the 13 to 14-inch group, but fluctuates only slightly thereafter. This behavior of the data constitutes good evidence that vulnerability to the gill nets remains substantially constant after a size of 13 inches is attained; for, if not, there would be a continued change in the rate of decrease under the netting program. The average value of b for the four largest groups corresponds to a rate of decrease of the population of 20.5 percent per single series of 5 sets. Even the 11- to 12-inch group does not differ *significantly* from the older ones, though a gradual rather than a sudden increase in vulnerability, as size increases, appears reasonable enough.

From Hart's (1931) age determinations on these fish it is evident that the length range from 13 inches up includes the mean length of the age groups from XI to XXVI. Since we have shown these fish to be uniformly vulnerable to the nets used, survival rates calculated from the age composition of the catch beyond age-group XI should be free from bias due to net selection. This limit of 13 inches or 330 millimeters mean length might serve also as a *rough* estimate of the limit of selectivity, for whitefish, of similar gangs of nets set in other lakes, though local information should be obtained wherever possible. In many fisheries a limit somewhat lower than this would be satisfactory because in them mortality is large compared to the effect of net selection. On Shakespeare Island Lake even a small amount of selection is disturbing because the mortality rate is so small (*cf.* below).

Even when the nets used take a reasonably representative sample, it does not always follow that investigators have done likewise, especially when samples have been taken without any thought of computing survival rate from them. Wherever it is not clear that investigators have taken either the whole of the fish available or a random sample of them, a direct inquiry has been made.

The sources of random error in estimating mortality from age frequencies include (1) ordinary sampling error and (2) error due to fluctuations in the supply of fish which are hatched in successive years, or which survive to become of catchable size. Ordinary sampling error is too well known to require further discussion. Error due to fluctuations in supply is classed as random because I find no evidence of trends in the distribution of recruitment in the unexploited populations considered here, although conceivably such trends could occur as a result of periodic meteorological phenomena or of cycles in population dynamics. Even considered solely as a random phenomenon, fluctuations in supply are a serious obstacle to the accurate estimation of survival rate from age frequencies. In a few examples they can be minimized by combining catches taken in successive years; otherwise the only method is to smooth the graph obtained for successive ages as well as possible. In this smoothing a running average of 3 has been used. This procedure distorts the slope of the resulting line somewhat whenever that slope is increasing, so that

the actual slope lags somewhat behind the slope determined by the unsmoothed data. However, on the parts of the catch curve from which survival rate can be estimated, the rate of change of slope tends to be small and the error introduced is imperceptible. Smoothing by three's is particularly convenient where a year class is missing: it is difficult to decide what weight to give the point, minus infinity, on the graph!

Unless otherwise indicated, in the examples to follow points on the graphs of age frequency always represent the logarithm of the number of fish of the age indicated plus the two adjacent ages, without dividing their sum by 3. This simple procedure was followed because it is only the relative position of the points that is of interest; multiplying or dividing by any constant number merely shifts the position of all the points up or down. The number of fish actually determined at each age is shown in Table 2.

TABLE 2.—*Number of fish used in computing survival rates in this study*

[(1) Sauger of Lake Nipigon; (2) Rock bass of Nebish Lake, males, 1931; (3) the same, males, 1932; (4) the same, females, 1931; (5) the same, females, 1932; (6) normal whitefish of Lake Opeongo, 1939; (7) the same, 1940; (8) "dwarf" whitefish of Lake Opeongo, 1940; (9) whitefish of Shakespeare Island Lake; (10) whitefish of Lake Nipigon. (After various authors)]

Age group	Code Number — see caption of table									
	1	2	3	4	5	6	7	8	9	10
0	...	...	...	...	...	62	50	4	...	...
I	...	...	...	...	...	38	82	39	9	2
II	...	10	78	9	59	41	47	15	11	14
III	5	6	43	7	59	57	22	3	1	14
IV	5	3	7	5	9	176	16	1	8	9
V	4	8	8	7	2	41	16	...	31	16
VI	6	5	3	11	8	60	3	...	12	14
VII	17	27	5	24	9	44	5	...	5	8
VIII	6	117	8	99	17	13	7	...	8	13
IX	8	18	41	47	74	8	1	...	11	14
X	5	4	10	17	33	2	1	...	2	24
XI	1	...	3	2	13	2	...	...	7	23
XII	6	...	...	1	3	1	...	...	10	13
XIII	1	...	...	...	1	...	...	...	9	22
XIV	...	...	...	...	...	...	...	...	6	7
XV	...	...	...	...	...	...	...	...	2	8
XVI	...	...	...	...	...	...	...	...	11	2
XVII	...	...	...	...	...	...	...	...	2	1
XVIII	...	...	...	...	...	...	...	...	3	3
XIX	...	...	...	...	...	...	...	...	5	2
XX	...	...	...	...	...	...	...	...	0	0
XXI	...	...	...	...	...	...	...	...	6	0
XXII	...	...	...	...	...	...	...	...	3	0
XXIII	...	...	...	...	...	...	...	...	0	1
XXIV	...	...	...	...	...	...	...	...	1	...
XXV	...	...	...	...	...	...	...	...	0	...
XXVI	...	...	...	...	...	...	...	...	1	...

In addition to the logarithms of frequencies, the graphs to be presented also give logarithms of mean weights of fish of successive ages, whenever possible. (The latter are indicated by crosses, the former by circles.) Both are plotted on the same logarithmic scale, so that direct comparison is possible between the rate at which an average year class is increasing in

weight and the rate at which it is decreasing in abundance. The age at which the slopes of the two curves are numerically equal (they are opposite in sign) marks the age at which any year-class attains its maximum bulk.

Sauger of Lake Nipigon

After a brief period of investigation of Lake Erie in the year 1922, the activities of the recently formed Ontario Fisheries Research Laboratory were directed to Lake Nipigon in the northwestern part of that province. This body of water was selected because fishing had begun there, on any considerable scale, only in 1917 (Dymond, 1926), and it was felt that the opportunity should be taken to investigate a large lake which was still, presumably, little modified by the exploitation of its fish resources. Among the numerous published results of four years' work on this lake is an account by Hart (1928) of the rate of growth of the yellow pike-perch or walleye (*Stizostedion v. vitreum*) and the sauger (*S. canadense*). In spite of the relatively short span of commercial fishing in the lake, sufficient time had elapsed to distort the age distribution of the populations of commercial fishes, notably whitefish and yellow pikeperch. The sauger, however, because of its smaller size, was practically untouched by the com-

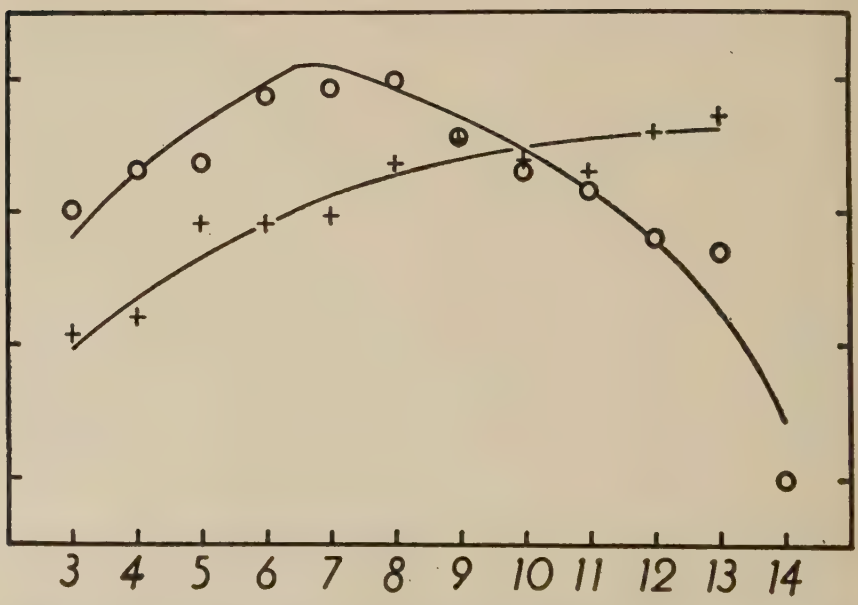

Figure 2. Logarithm of frequency (circles) and logarithm of weight (crosses) for the sauger of Lake Nipigon (data from Hart, 1928). In this and later figures the ordinate divisions represent 0.5 log unit, and the abcissa shows age in years completed.

mercial gear in use, and the relative numbers taken in experimental gill nets afford information concerning their primitive survival rate.

The catch curve (Fig. 2) is taken from Hart's Table 1. It has a mode at age-group VII, and from age-group IX onward the estimated survival rates given below are likely to be free from systematic error:

Age group	*s.*	*Age group*	*s.*
VIII–IX	0.77(?)	XI–XII	0.66
IX–X	0.74	XII–XIII	0.53
X–XI	0.70	XIII–XIV	0.40

Rock Bass of Nebish Lake

Nebish Lake is a lake of 38.5 hectares extent, in Vilas County, Wisconsin. Hile (1941) studied its rock bass (*Ambloplites rupestris*) from samples taken 1930–1935, and he advises that the population had scarcely been exploited at all at the time these samples were taken.

For determination of mortality rate the collections of 1931 and 1932 are most useful. These collections were taken by means of gill nets of 1¼, 1½, 1¾, 2, 2¼, 2½, and 3 inches, stretched mesh, and Hile's discussion of the wide range of sizes taken by each of these nets makes it certain that sampling was close to representative among the older fish. On the other hand, the catch curves obtained have very broad domes, indicating that it is *only* the oldest fish which can be used to estimate survival. The data are taken from Tables 14 and 15 of Hile's work. Starting at age-group V, for each year and each sex separately the age groups were combined by threes to smooth out effects of variable recruitment. Since curves for the two years were similar, they have been combined to give the best average picture, assigning each year the same weight (Fig. 3). A curve for the age groups as a whole was also drawn, by combining the representation of the two sexes in the number in which they actually occur, then proceeding as before.

The derived survival rates are shown in the schedule below:

Age group	*Males*	*Females*	*Combined*
X–XI	0.23	0.38	0.34
XI–XII	0.12	0.30	0.29
XII–XIII	....	0.27	0.22
XIII–XIV	....	0.21	0.21

Since the fish involved represent only the oldest quarter of the population, it is not surprising to find survival so poor. The very fact that fish this old exist is fairly good evidence that at younger ages survival is much better, but these data give no information concerning its actual magnitude.

The rate of growth of male rock bass in Nebish Lake is greater than that of the females. However, because of the greater mortality rate of old

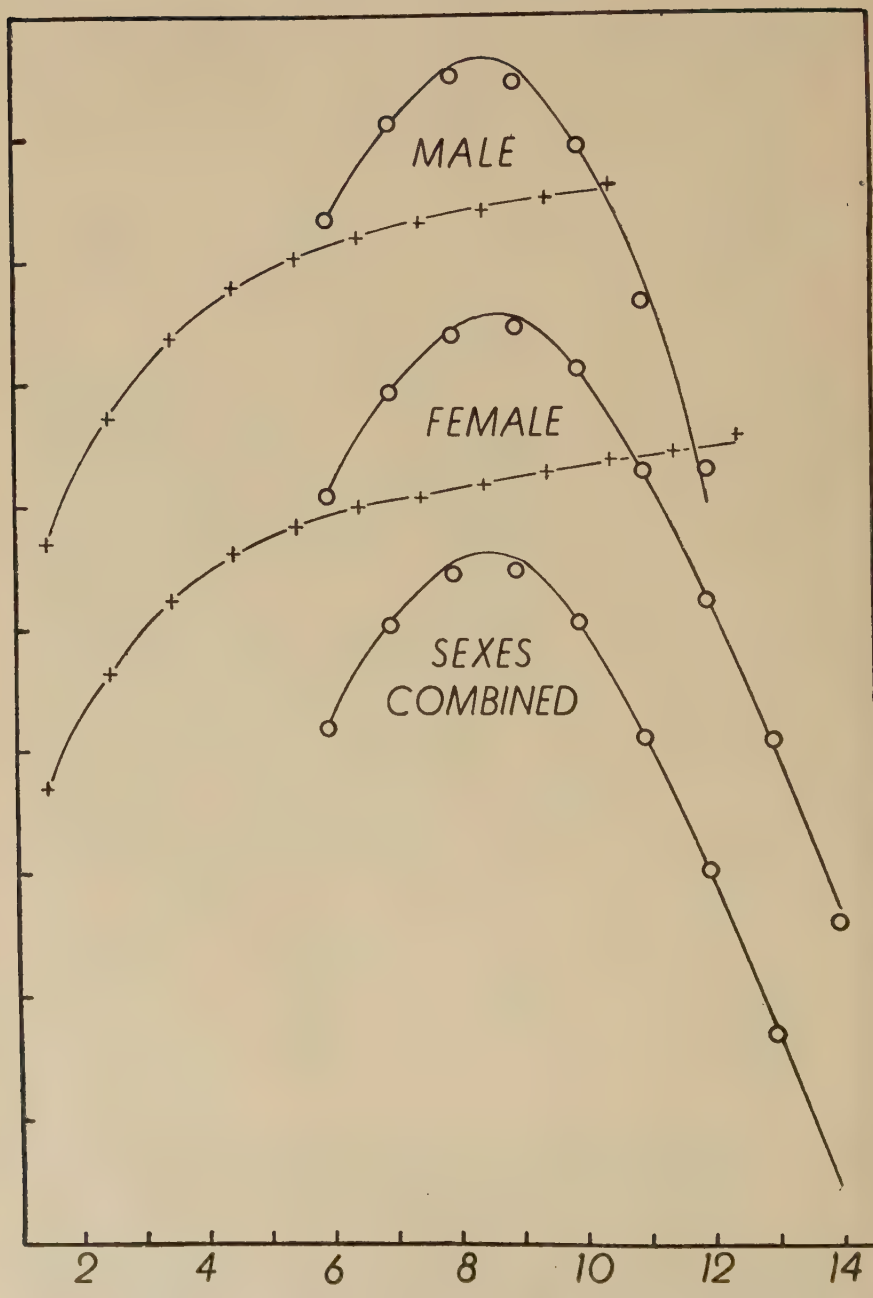

FIGURE 3. Logarithm of frequency (circles) and weight (crosses) for the rock bass of Nebish Lake (data from Hile, 1941). See also caption for Figure 2.

males, the largest specimens taken of each sex were much the same size (Hile, Table 20). It would be interesting to determine whether size and mortality were *directly* associated.

The relative rate of growth of both sexes of the Nebish Lake rock bass falls off rapidly at age-groups V–VII, and the age at which a year class reaches its maximum bulk is evidently considerably less than the youngest age at which survival can be measured.

Whitefish of Lake Opeongo

Lake Opeongo is a lake of 20.5 square miles extent in Algonquin Park, Ontario. Its whitefish (*Coregonus clupeaformis*) were studied by Kennedy (1943) at a time when they constituted a practically unexploited population. The lake had been fished commercially during World War I, but not subsequently, so that by 1936, when Kennedy's first samples were taken, no year class remained that had survived from that period. Opeongo whitefish are rarely taken by sport fishermen. A complication was introduced by the fact that two distinct types of whitefish were present in the lake, the "dwarfed" and the "normal", differing sharply in rate of growth and age at maturity.

Two curves for the "normal" race are presented (Fig. 4), based on the two years 1939 and 1940. These were taken almost wholly in gill nets ranging in size from 1 to 5 inches, inclusive (stretched mesh). In 1939 special efforts were made to take large fish, but in 1940 netting was done with three graded gangs of nets in a systematic manner. The slopes of the two curves, at comparable ages, differ very little in the age range VI–VIII, beyond which point the 1940 curve is based on very few specimens. It would be tempting to make estimates of survival at ages younger than VI for the 1940 curve, but the probability of selective capture suggests caution.

Survival rates computed from Figure 3 are as follows:

Age	*1939*	*1940*
VI–VII	0.59	0.59
VII–VIII	0.53	0.56
VIII–IX	0.50	0.53
IX–X	0.46	0.52
X–XI	0.45	0.44
XI–XII	0.44	....
XII–XIII	0.41	....

The catch curve of the dwarf whitefish taken in 1940 is also shown in Figure 4. Apparent survival rates are 0.36 for age-groups I–II, 0.26 for age-groups II–III, and 0.22 for age-groups III–IV. Because of net selection, these figures are probably somewhat too high to be representative, but even so they are much lower than those encountered among even the oldest of the "normal" whitefish.

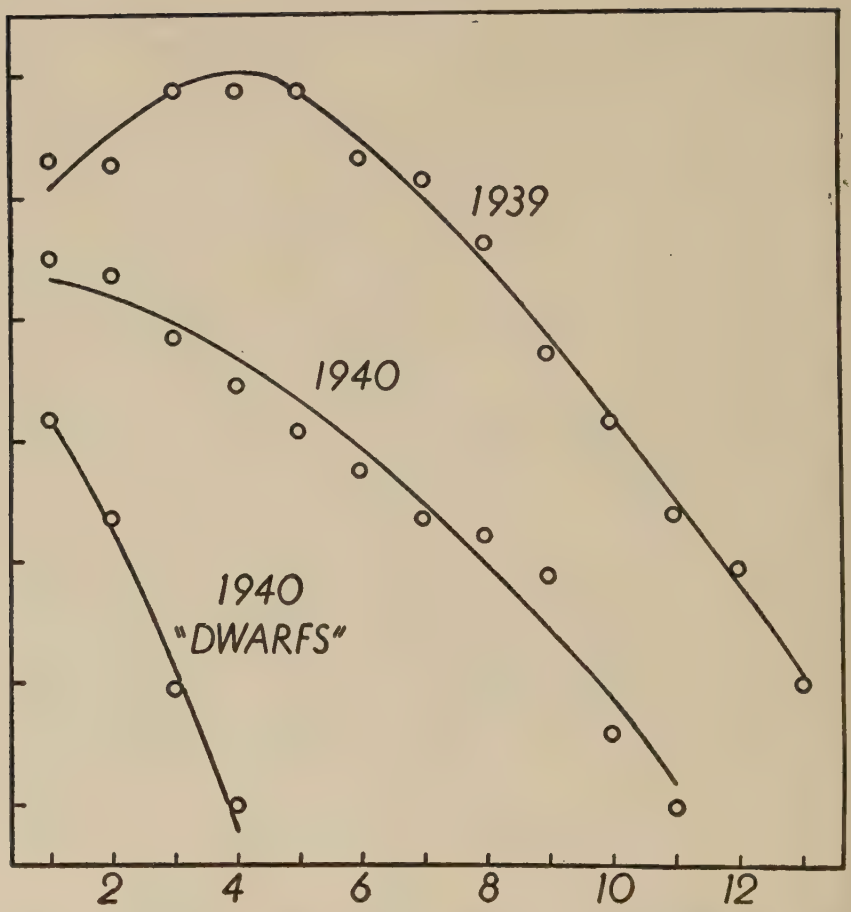

FIGURE 4. Logarithm of frequency for the whitefish of Lake Opeongo (data from Kennedy, 1943). See also caption for Figure 2.

WHITEFISH OF SHAKESPEARE ISLAND LAKE

This small lake, situated on an island in Lake Nipigon, Ontario, was mentioned in the introduction. When investigated in 1925, it had not been regularly fished, though a few catches had evidently been made (Hart, 1932). Age determinations on scales taken during the netting experiment of 1925 have been reported by Hart (1931). Only a small part of the total catch was examined in this way. However, the distribution of lengths in it apparently parallels that of the total catch, in the region beyond the limit of net selectivity (330 millimeters), so sampling from the

catch was apparently reasonably random over the age range which is of interest here. The catch curve (Fig. 5) indicates a high survival rate almost throughout life. As noted in the introduction, fish older than age-group XI in this lake are randomly sampled, and above that limit survival is at a phenomenally high level up to age-group XX, as shown below:

Age group	*s*	*Age group*	*s*
XI–XII	0.92	XIX–XX	0.83
XII–XIII	0.91	XX–XXI	0.79
XIII–XIV	0.90	XXI–XXII	0.76
XIV–XV	0.89	XXII–XXIII	0.73
XV–XVI	0.89	XXIII–XXIV	0.68
XVI–XVII	0.88	XXIV–XXV	0.64
XVII–XVIII	0.87	XXV–XXVI	0.60
XVIII–XIX	0.85	XXVI–XXVII	0.55

Of course, a rather low mortality rate was to be expected in this lake simply from the fact that fish as old as age-group XXVI occurred at all in a population which apparently numbered only 1,500–2,000 individuals. In that connection it can be noticed that, although his study was undertaken with a view to estimating the population of the lake, Hart (1932) is cautious about coming to any conclusion concerning its actual size. An estimate of abundance, by 2-inch length intervals, can be computed from the regression coefficients of Table I (except that the interpolated value $b = 0.038$ is used for the 9 to 10-inch class). Each coefficient is multiplied by 7 and the antilog then determined to give the percentage of the population that survived the seven series of net sets. The complement of this figure is the total percentage decrease which, divided into the catch, gives the following estimate of the original population in each length class:

Length class (fork length in inches)	*Percentage decrease*	*Catch*	*Population (pieces)*	*Population (pounds)*
7– 8	35	133	390	117
9–10	46	227	494	260
11–12	54	199	368	305
13–14	80	109	136	171
15–16	71	128	180	358
17–18	86	96	112	363
19–20	72	24	33	124
Total		916	1713	1698

Associated with the low mortality rate of the Shakespeare Island Lake whitefish is a slow rate of growth; fish in excess of 20 years old weighed 4–5 pounds. The weight of the population is computed above from the

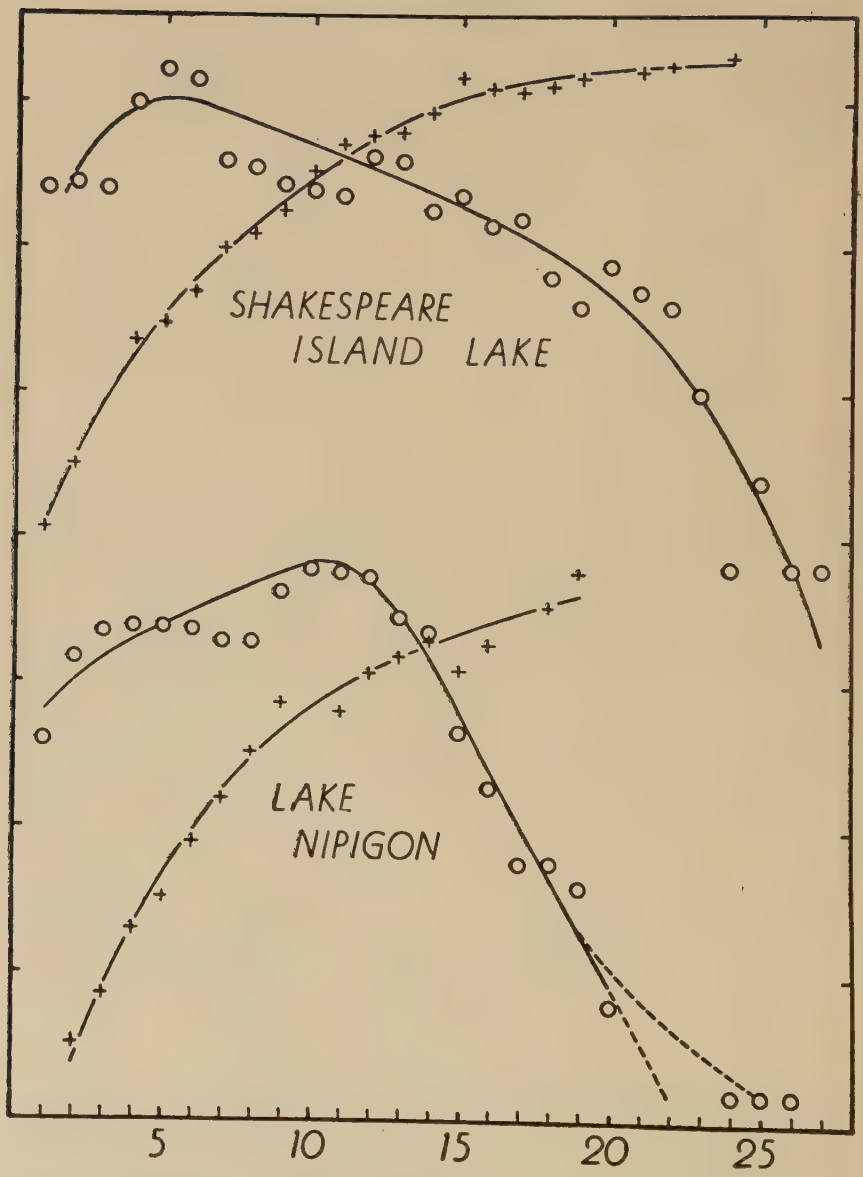

FIGURE 5. Logarithm of frequency (circles) and weight (crosses) for whitefish (data from Hart, 1931). See also caption for Figure 2.

length-weight relationship of Hart (1931, Fig. 2) using 1.09 as the factor to convert from standard to fork length; it amounts to 21 pounds per acre. As shown in Figure 5, the relative rate of growth decreases throughout life and is overtaken by the mortality rate between age-groups XII and XIV, at which ages an average year class would be at its maximum bulk.

Whitefish of Lake Nipigon

The Nipigon population of whitefish was sampled in 1923–24 at which time it had experienced several years of fairly intensive exploitation. It is introduced here for comparison with the primitive population of Shakespeare Island Lake. The catch curve of Nipigon whitefish taken in gill nets of graded sizes, plus a few from commercial nets of 4½-inch stretched mesh, is shown in Figure 5 (data from Hart, 1931). Throughout the range of commercial sizes the survival rate is much less than at corresponding ages in the Shakespeare population, being about 64 percent per year from age-group XIII to age-group XX. Beyond age-group XX a single fish of the XXIII group deflects the catch curve and thus faintly suggests the greater survival rates of an earlier decade.

To illustrate the kind of use we should *like* to make of data of this sort, the instantaneous mortality rate for commercial sizes of Nipigon whitefish can be taken as $i = -\log_e 0.64 = 0.45$. If Shakespeare Island fish could be taken as representative of Lake Nipigon before exploitation started, the primitive value of i in this age range would be about $i = -\log_e 0.88 = 0.13$. The difference, or 0.32, would be an estimate of the instantaneous rate of fishing mortality which obtained on Lake Nipigon during the early 1920's.

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MORTALITY, RATE OF GROWTH, AND FIN REGENERATION OF MARKED AND UNMARKED LAKE TROUT FINGERLINGS AT THE PROVINCIAL FISH HATCHERY, PORT ARTHUR, ONTARIO

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ABSTRACT

The experiment was initiated in an attempt to determine the effect resulting from the excision of the adipose fin of lake trout (*Cristivomer namaycush*). The experimental fish (500 marked and 500 unmarked) taken at random from fish handled during the daily clipping operations were weighed and measured and placed in two troughs allocated for the experiment.

In June 1948 after a lapse of 10 months the fish were counted and examined. The aggregate loss was 13 or 2.6 percent of the marked fish and 20 or 4.0 percent of the unmarked fish. Measurements indicated no appreciable difference in the length and weight. The growth increments were 4.59 centimeters and 6.79 grams in marked fish and 4.56 centimeters and 6.77 grams in the unmarked fish. A total of 24 or 4.9 percent of marked fish exhibited varying degrees of regeneration. Of this total, 17 fish or 3.47 percent could be identified as marked fish.

INTRODUCTION

In August 1947 a relatively extensive clipping program was conducted at the Port Arthur Fish Hatchery. The adipose fin (fatty fin) was removed from 43,790 lake trout. As an adjunct to the clipping experiment a number of clipped and unclipped fish were placed aside in special control troughs. These fish were retained over winter in order that a study on the effect of fin-clipping could be determined from a comparison of the mortality, rate of growth, and fin regeneration. The following paper will describe the results attained during the observation period of 10 months.

METHOD

The procedure adopted for this experiment followed the method described by Shetter in a similar experiment conducted at Marquette, Michigan.[1] While the clipping operation was in progress in 1947, 500 clipped and 500 unclipped fish were placed in two control troughs. These fish, taken at random, were weighed and measured in order that a comparison could be made at a later date. The measurements were taken while the

[1] Shetter, David S., 1947. Progress report on the control experiments involving marked and unmarked lake trout fingerlings at the State Fish Hatchery, Marquette, Michigan. Report No. 1091. Institute for Fisheries Research, Michigan Department of Conservation. (Typewritten)

fish were anesthetized and the weights were determined by weighing groups of 25 in water.

The fish were placed in two similar 14-foot troughs at the Port Arthur Fish Hatchery. Side boards were erected bordering the troughs to prevent any loss of fish through jumping.

Comparative Mortality

On completion of the clipping program in 1947, a constant observation of the control fish was maintained by the hatchery staff and all mortalities detected were noted and recorded during the experimental period.

Early in June 1948 the fish were counted and examined. The total mortality for the period between August 15, 1947, and June 15, 1948, was found to be 13 fish or 2.6 percent of marked fish and 20 or 4.0 percent of unmarked fish. In this experiment, therefore, clipping cannot be demonstrated to have been a source of mortality.

The total mortality, while disclosing the actual number of fish lost, does not correspond exactly with loss detected by the hatchery staff. It is therefore necessary to divide the total loss into two categories: detected and undetected. The total detected loss revealed a mortality of 10 clipped

Table 1.—*Detected and undetected mortality of lake trout during the 10-month period*

Control fish	Total count, August, 1947	Detected loss	Undetected loss	Total count, June, 1948
Clipped fish.....	500	10	3	487
Unclipped fish.....	500	15	5	480

and 15 unclipped fish, a difference of 3 and 5 fish respectively from the total loss by count (Table 1). The difference between the detected and undetected losses can be explained only by cannibalism.

Comparative Growth Rate

When the investigation was initiated in 1947, all fish set aside for the experiment were measured and weighed. The unmarked fish averaged 4.48 centimeters in standard length and 1.21 grams in weight. The average size of the marked fish was 4.56 centimeters and 1.25 grams. The fish were measured individually from the most anterior part of the head backward to the end of the vertebral column. The approximate weight was determinted by weighing 25 fish in water on "Precision Scales." These scales registered the weight in ounces.

On examination of these fish in 1948, similar methods were adopted in determining the length and weight. The average size of unclipped trout was 9.04 centimeters and their weight was 7.98 grams. The clipped fish

averaged 9.15 centimeters and 8.04 grams. The comparison of growth (Table 2) reveals no difference between clipped and unclipped lake trout.

TABLE 2.—*Increment of growth of the marked and unmarked lake trout fingerlings*

Date of examination	Clipped fish		Unclipped fish	
	Length (centimeters)	Weight (grams)	Length (centimeters)	Weight (grams)
August, 1947	4.56	1.25	4.48	1.21
June, 1948	9.15	8.04	9.04	7.98
Increase	4.59	6.79	4.56	6.77

FIN REGENERATION

In the examination of the adipose fins of the 487 clipped fish five degrees of regeneration (none, ¼, ½, ¾, and full) were used to express the varying amounts of regeneration. Fins showing any regeneration, regardless of pattern were recorded in one of the categories.

With the above criterion, the results were as follows: no regeneration, (463) 95.1 percent; ¼ regeneration (10) 2.0 percent; ½ regeneration (7) 1.4 percent; ¾ regeneration (1) 0.2 percent; and full regeneration (6) 1.2 percent. Thus, less than 5 percent exhibited any regeneration at all and only a little more than 1 percent had fully regenerated fins.

ACKNOWLEDGEMENTS

The author wishes to give thanks to Mr. G. K. Manore (Hatchery Manager) and staff for their helpful suggestions and willing assistance during the experiment.

RE-FORMATION OF EXCISED FINS OF KING SALMON FINGERLINGS AND ITS EFFECTS ON RECOGNITION OF MARKED ADULTS

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Abstract

In marking experiments with king salmon (*Oncorhynchus tshawytscha*) fingerlings at Coleman Fisheries Station, California, in 1945 and 1946 half the fingerlings were held over for 6 months after marking. The extent of fin re-formation was studied during these periods. Standards based on the numbers of rays present were used in grading except in the adipose fin where size was the basis.

Accidental suffocation of 1,200 fingerlings marked by removal of the adipose and left ventral fins provided a sample for careful analysis. These fish had been marked 3 months previously, but another 2,099 fingerlings from the same lot were examined at the time of release. Approximately 72 percent of these fish showed no or negligible fin re-formation; 21 percent had partially re-formed fins; 5 to 8 percent exhibited considerable re-formation.

Of the fingerlings marked by removal of the left ventral and dorsal fins, 2,367 were examined at the time of release. In this lot 87 percent had no or negligible fin re-formation; 6 percent partial; and 7 percent considerable.

Examination of 2,192 fingerlings marked by removal of the left ventral and anal fins was likewise made at the time of release. Eighty-one percent showed either no or negligible re-formation; 6 percent partial; and 13 percent considerable.

Decided differences were shown in the extent of re-formation among the four fins studied.

Correlation analysis of quality of mark in relation to length of fish was also made. The ventral fin showed slight correlation whereas the dorsal fin showed none.

The marking of 2-inch king salmon fingerlings by fin removal begun in the spring of 1945 and continued in the spring of 1946 as a phase of the Shasta salmon-maintenance investigations has provided information on the re-formation of excised fins. In each of three experiments, the fish of one of each pair of marks were retained and fed from the time of marking in April until the time of release in October. This procedure made possible the examination of the condition of the fins after 6 months' growth.

The fin clipping was accomplished by local women using 4-inch bone forceps maintained in good cutting order by careful honing. In 1945 the markers were completely inexperienced, but in 1946 about 25 percent of the fish were marked by persons experienced by having marked in 1945. Individual instruction was given all markers and frequent checks on the quality of the marks were made in both years (but more intensively in 1946).

Equal assortment of the fish to the paired marks was accomplished in 1945 by having the markers clip approximately equal numbers of each of both marks daily. Over the course of the marking, each person clipped approximately equal numbers from the 10 troughs in which the fish were held. This procedure proved too involved, so that in 1946 the paired marks were clipped on alternate days with all persons making the same mark on any one day.

After some experimentation a set of standards was developed for grading the individual fins as to degree of re-formation (Table 1). In the rayed fins, these standards are based on the numbers of full-length or

TABLE 1.—*Standards used in grading the condition of the fins on marked king salmon fingerlings*

Degree of fin re-formation	Adipose (no rays)	Anal (approximate average, 16 rays)	Dorsal (approximate average, 13 rays)	Ventral (approximate average, 10 rays)
None	No tag	No normal ray[1]	No normal ray[1]	No normal ray[1]
Negligible	No tag	1– 3 rays	1– 2 rays	1 ray
Partial	Small tag	4– 7 rays	3– 6 rays	2– 4 rays
Considerable	Unremoved	8–16 rays	7–13 rays	5–10 rays

[1] Curl or stub allowed. The term "curl" refers to a small, contorted remnant composed of one or two rays and usually consisting of one ray of nearly full length but so deformed and twisted as to be obviously abnormal. The term "stub" refers to a small remnant composed of parts of one or two rays forming a short, thickened, and blunt structure that is obviously abnormal.

nearly-full-length, normally disposed rays that are present (Fig. 1). The numbers of rays (Table 1) were selected to correspond roughly to percentages of the total areas of the fins as follows: first grade, 0 to 5; second grade, 6 to 10; third grade, 11 to 40; and fourth grade, 41 to 100. Since the adipose fin is small, fleshy, without rays, and apparently non-regenerative, its standards are not comparable to those of the other fins, and only three grades could be distinguished.

The numbers of rays given for the complete unmarked fins (Table 1) do not necessarily correspond with the numbers recognized by taxonomists, since the short rays near the origins of the dorsal and anal fins were also counted. Justification for counting these short rays is to be found in Figure 1b; the rays shown are assumed to have been formed by regeneration of the origins of the short rays, since a large percentage of the re-formed elements of both the dorsal and anal fins were of this type as will be shown later. No attempt has been made in this study to distinguish among actual regeneration, re-formation from partially removed parts, or non-removal as the source of the fin elements observed. The term "re-formation" is used herein to include all the observed fin structures from whatever source even though these structures may not have been actually re-formed.

In 1945 a sample of 1,200 marked fingerlings was provided when this number was accidentally killed by suffocation of part of the fish in one

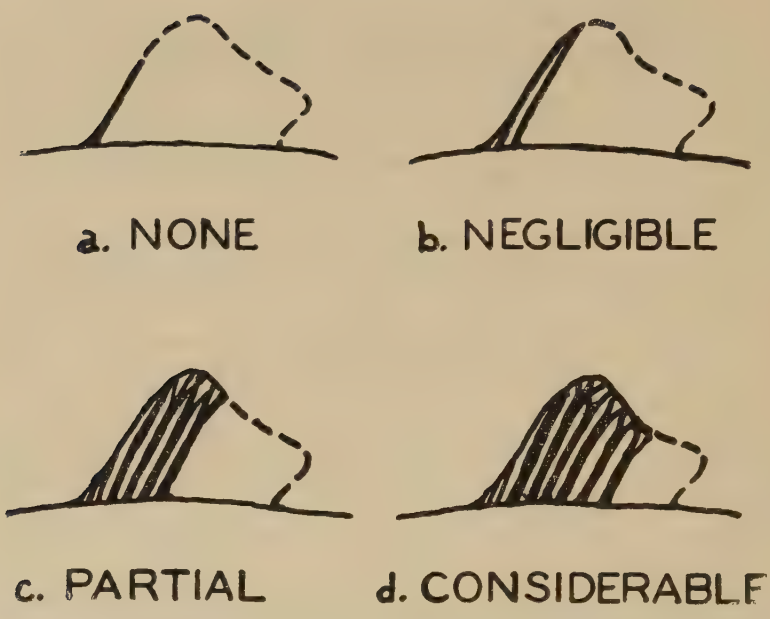

FIGURE 1.—Comparison of grades of re-formation of the dorsal fin of marked king salmon fingerlings

trough on July 19, approximately 3 months following marking. This sample is believed to be representative of the population, since the entire group from which it was obtained had just recently been returned to troughs without selection after having been confined together in a single pond for over 2 months. These fish had been marked by removal of the left ventral and adipose fins. Each fish was examined with the aid of a low-power binocular microscope and graded (Table 2) according to the standards set down in Table 1.

TABLE 2.—*Summary of examination of 1,200 king salmon fingerlings marked by remova of the left ventral and adipose fins*

Degree of fin re-formation		Number of fish	Percentage	Fiducial limits[1] (percentage)
Ventral	Adipose			
None	None	613	51.08	±2.96
Negligible	None	235	19.58	±2.25
Partial	None[2]	256	21.33	±2.20
Considerable	None[3]	96	8.00	±2.10

[1] Plus or minus the product of t at the 5-percent level (from Snedecor, 1946:65) and the standard error of the mean of 14 sub-samples
[2] Includes four fish with small adipose tag
[3] Includes 22 fish with adipose unremoved; 4 marked right ventral; others as indicated

The same group of fish from which the above sample was obtained was sampled again October 16–18, 1945, at the time they were counted and released. Of 42,181 fingerlings released, 2,099 were examined (Table 3).

TABLE 3.—*Summary of examination of 2,099 king salmon fingerlings marked by removal of the left ventral and adipose fins*

Degree of fin re-formation		Number of fish	Percentage	Fiducial limits[1] (percentage)
Ventral	Adipose			
None	None	1,194	56.88	±2.37
Negligible	None	341	16.25	±1.91
Partial	None[2]	450	21.44	±2.52
Considerable	None[3]	114	5.43	±1.13

[1] Plus or minus the product of t at the 5-percent level (from Snedecor, 1946:65) and the standard error of the mean of 21 subsamples
[2] Includes 17 fish with adipose tag
[3] Includes 17 fish with adipose unremoved; 8 marked right ventral; 2 with both ventrals and adipose removed; others as indicated

These data do not agree precisely with those of the examination summarized in Table 2. This discrepancy was to be expected in view of the difference in the methods of sampling and examination. The data of Table 2 resulted from the examination of preserved fish with the aid of a microscope whereas those of Table 3 are the result of field examination of live fish. It is conceivable, also, that some changes actually may have occurred over the 3-month period. Casual observation indicates that many, if not all, of the small deformed curls degenerate and slough off in time, and common experience shows that the "pinheads" or runts make up a greater relative proportion of the normal mortality than do the larger individuals. As will be shown below, the small fish re-form their ventral fins to a somewhat greater extent. The sloughing of curls and the selective mortality would tend, in a slight degree, to produce the observed differences. Furthermore, whereas the selection of the sample summarized in Table 2 was probably random, that of Table 3 may have involved an unconscious bias in favor of the larger fish. The fish were picked up one at a time from a netful in the latter observations. Hewitt and Burrows (1948) have shown that fish confined in a net are stratified with the larger fish at the surface.

The differences between the data of Tables 2 and 3, although statistically significant, are small, so that either set can be used as a practical guide to the success of the marking. These data indicate that around 72 percent (first two categories) were so distinctly marked that no difficulty would be experienced in identifying them at a glance. Another 21 percent could be identified on closer scrutiny, and between 5 and 8 percent could be identified only with difficulty, if at all.

Both groups of fingerlings marked in 1946 were sampled and examined just prior to release, that is, about 6 months after marking. On October 3 and 4, 1946, the fingerlings marked by removal of the left ventral and

dorsal fins were weighed and counted. Of the 41,413 counted, 2,367 were examined for condition of the fins. The subsamples were obtained by taking approximately one-fourth of every third tubful weighed. Twenty-two unbiased subsamples were thus obtained. The technique of the sampling has been described by Hewitt and Burrows (1948). Briefly, it consists of obtaining a representative cross-section of the population by employing a sectioned basket within the weighing vessel. The basket used here was constructed on a frame of light steel rods shaped to fit snugly within an ordinary washtub (weighing vessel). The sides of the basket were of wire-screen cloth. The bottom was open except for the crossed rods outlining the sections (quarters used here) and served for attachment and support of bobbinet tubes. The actual quarters were defined by the bobbinet tubes. These tubes were inoperative until the basket was lifted from the bottom of the weighing vessel. In sampling, one of the tubes was closed off at the bottom to form a pouch while the other three provided a uniformly white bottom.

It will be noted in the summary of the results of this examination (Table 4) that the categories differ from those of Tables 2 and 3. These differences cannot be avoided because of the important structural differ-

TABLE 4.—*Summary of examination of 2,367 king salmon fingerlings marked by removal of the left ventral and dorsal fins*

Degree of fin re-formation		Number of fish	Percentage	Fiducial limits[1] (percentage)
Ventral	Dorsal			
None None Negligible	None Negligible None	1,568	65.46	±3.07
Negligible None Partial	Negligible Partial None	498	21.71	±2.37
Negligible Partial	Partial Negligible	134	5.60	±0.70
Partial Considerable Any	Partial Any Considerable	167	7.23	±1.40

[1] Plus or minus the product of t at the 5-percent level (from Snedecor, 1946:65) and the standard error of the mean of 22 subsamples

ences between the adipose and dorsal fins. However, the groupings are thought to be comparable on the basis of recognition of the mark. Any substantial mutilation of the dorsal fin would undoubtedly be more easily recognized than a complete removal of the adipose fin due to the much greater prominence of the former on an unmarked fish.

The results summarized in Table 4 indicate that approximately 87 percent of these fingerlings were distinctly marked so that no difficulty would be experienced in identifying them. An additional 6 percent could

be identified on closer examination, and around 7 percent could be identified only with difficulty if at all. These fish were better marked than those marked in 1945 as will be discussed below.

The fingerlings marked by removal of the left ventral and anal fins were counted on September 30, 1946. They had been weighed on September 24. Of the 41,918 counted, 2,192 were examined for condition of the fins. Subsamples to be examined were obtained in a manner similar to that used on the above fingerlings, that is, approximately one quarter of a tub of fish was used as a subsample and samples were taken throughout the entire group as the counting progressed. However, the actual subsamples were not recorded separately. Only three larger subsamples were distinguished in recording the data. The fiducial limits on this group are therefore greater. The grading categories for the mark are as in Table 4. The results of the examination are summarized in Table 5.

TABLE 5.—*Summary of examination of 2,192 king salmon fingerlings marked by removal of the left ventral and anal fins*

Degree of fin re-formation		Number of fish	Percentage	Fiducial limits[1] (percentage)
Ventral	Anal			
None None Negligible	None Negligible None	990	45.17	±9.40
Negligible None Partial	Negligible Partial None	782	35.67	±2.34
Negligible Partial	Partial Negligible	131	5.98	±3.19
Partial Considerable Any	Partial Any Considerable	289	13.18	±10.88

[1] Plus or minus the product of t at the 5-percent level (from Snedecor, 1946:65) and the standard error of the mean of three subsamples

The data of Table 5 indicate that approximately 81 percent of the fingerlings were so distinctly marked that no difficulty would be found in recognizing them; another 6 percent would require closer scrutiny for identification; and 13 percent could be identified only with difficulty if at all.

From comparison of Tables 4 and 5 it is evident that the anal fin is either more difficult to mark than the dorsal fin or has a greater capacity for regeneration. It is probable that both factors have contributed to the observed result. A more detailed comparison of the degree of re-formation of the four fins discussed here is given in Table 6. These data demonstrate decided differences in the regenerative power and/or the difficulty of permanent removal among the four fins.

The adipose, of course, proved the least difficult from which to produce a permanent mark. Among the rayed fins, the 1946 results indicate that

TABLE 6.—*Comparison of the degree of re-formation of different fins of marked king salmon fingerlings after 6 months' growth*

Degree of fin re-formation	Percentage of total examined and fiduciall lmit[1]				
	Adipose 1945	Anal 1946	Dorsal 1946	Left ventral	
				1945	1946
None	98.14±0.63	11.59± 3.14	33.29±2.31	57.89±2.58	78.83±1.06
Negligible	.....	44.02±17.84	44.70±3.42	16.39±1.93	7.46±0.75
Partial	0.91±0.54	40.15± 9.09	19.94±2.72	21.11±2.60	12.88±0.90
Considerable	0.95±0.41	4.24± 6.15	2.07±0.65	4.62±0.93	0.83±0.39

Fiducial limit expressed as the product of t at the 5-percent level (from Snedecor, 1946:65) and the standard error of the mean of the subsamples. For the adipose and left ventral in 1945 there were 21 subsamples; for the anal in 1946 there were only 3 subsamples; for the dorsal in 1946 there were 22 subsamples; and for the left ventral in 1946 there were 25 subsamples

the ventral was the least difficult, the dorsal intermediate, and the anal most difficult from which to produce a permanent mark.

It is obvious that recognizable returns from the several marks considered here will differ relatively as the regenerative power and/or difficulty of marking of their constituent fins differ. Differences in returns would probably be small were it possible for a trained observer to scrutinize carefully each returning fish. This is rarely possible with returning salmon. Consequently, since the initial, and therefore determining, recognition of the mark must be made at a glance in commercial establishments by untrained observers, these differentials must be considered in the evaluation of returns. Comparison of other than paired marks is at times desirable. Such comparisons cannot be made safely without consideration of these differences in difficulty of recognition.

It is self-evident that the size of the fish at the time of marking will affect the quality of the mark. Very small fish (that is young fish) can be expected to have a relatively large capacity for regeneration which will decrease as they grow larger and older. More important, probably, to the quality of the mark are the mechanical difficulties connected with the minute size and transparency of the fins of the small fish. The length-frequency distribution of 1,306 fingerlings making up part of the mortality following marking for one of the groups marked in 1946 was plotted (Fig. 2). Mortality of this group was exceptionally high because *columnaris* disease was present. This condition may account for the fact that their average length, 58.52 ± 4.60 millimeters (and probably also their length-frequency distribution), corresponds fairly well with the average length, 58.9 millimeters, of the living fingerlings as calculated from their average weight at the end of the heavy mortality period. The fish were collected and preserved over a 5-day period shortly after marking but were measured a little over a year later. Since live fish were weighed 4 days after the dead onces were collected, the difference between the two estimates is in the expected direction. The average length of the other group marked in 1946, as calculated from the weight data, was 55.1 millimeters 5 days

following marking, and that of the group marked in 1945 was 55.6 millimeters 8 days following marking.

In order to obtain information on the importance of size in determining the quality of the marks, a sample of 432 fingerlings averaging 51.08 ± 4.22 millimeters in length was taken from spring-run fingerlings which died and were preserved immediately after the April 1946 marking. They were marked by removal of the left ventral and dorsal fins. The grading standards given in Table 1 were difficult to apply to these fish since no re-formation of the fins had taken place. Consequently the grading was necessarily more subjective and less accurate than that made on larger fish. The grade and the fork length (tip of the snout to the ends of the short rays in the tail) in millimeters were recorded for each fish. Correlation was made possible by assigning numerical values to the grades. A fin with no apparent re-formation was accorded 4 points, a fin with negligible

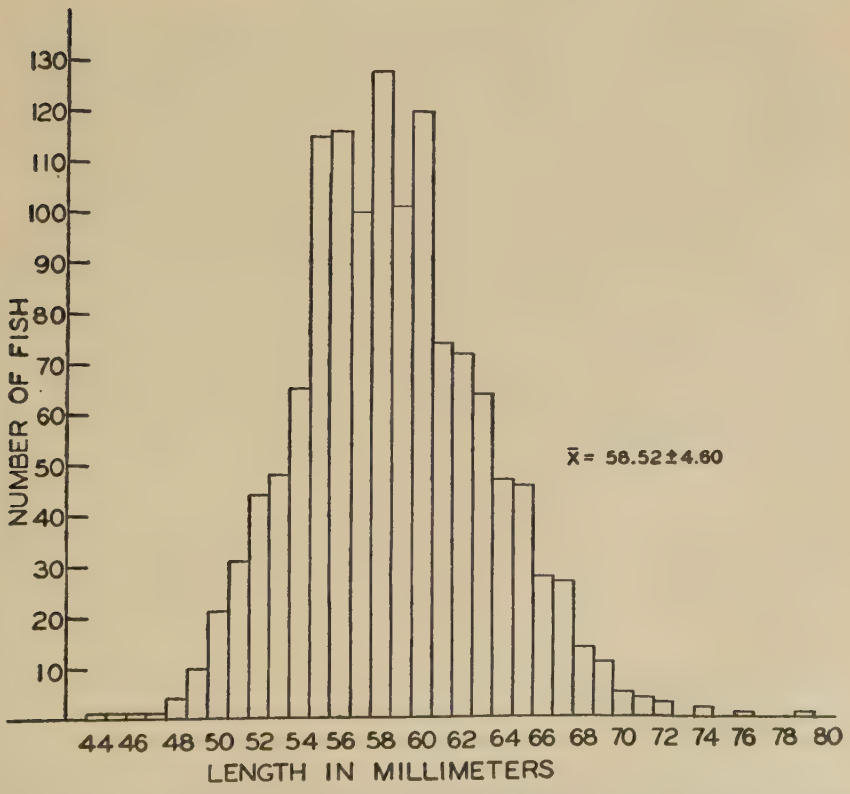

FIGURE 2.—Length-frequency distribution of 1,306 king salmon fingerlings marked at Coleman Station, California, in 1946

apparent re-formation 3 points, a fin with partial apparent re-formation 1½ points, and a fin with considerable apparent re-formation 0 point. The partial grade was assigned 1½ points in view of the fact that it is roughly twice as inclusive as the two higher grades and thus corresponds to an average of grades assignable to 2 and 1 points respectively.

For the above-mentioned sample of 432 small fingerlings, the correlation of the score for the ventral fin on length gave a coefficient, *r*, of 0.18 which is significant at $p = 0.01$ as measured by the *zeta* transformation of Fisher. The coefficient of 0.03 for the dorsal fin is insignificant.

Another analysis of the same group was made on a preserved sample of 392 fingerlings which died August 6, 1946 (about 3½ months after marking) from *Ichthyophthirius* parasitization. This sample averaged 88 millimeters in total length. The correlation for the left ventral fin score on length gave a coefficient, *r*, of 0.20 which is significant at the 1-percent level. The coefficient of 0.08 from the dorsal fin correlation is insignificant even at the 5-percent level.

Correlation analysis was made also on the 1,200 fingerlings marked by removal of the left ventral and adipose fins which were discussed above (Table 2). These fish averaged 79 millimeters long and were preserved about 3 months after marking. For the ventral fin the coefficient, *r*, is also 0.20. The fiducial limits are 0.17 to 0.22 at the 5-percent level of significance.

It is evident from these analyses that length variation within the range of a single age group contributes but little to the variation in quality of marks. The correlations for the ventral fin indicate only a 4-percent dependence of marking score on length. Observations on the various ages of fingerlings indicate that the slight correlation that does exist with the ventral fin is due not to the greater regenerative capacity of the fins of the small fish but to the difficulty of seeing and removing the smaller fins. Since the quality of the dorsal-fin mark is independent of size of the fish at the time of marking (within the range tested), it must depend on the skill of the marker in removing the origin of the fin.

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RESULTS OF VARYING THE RATIO OF LARGEMOUTH BLACK BASS AND BLUEGILLS IN THE STOCKING OF EXPERIMENTAL FARM PONDS

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ABSTRACT

During the period 1943 to 1946, several combinations of largemouth black bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) were stocked in ponds on the station grounds at Leetown, West Virginia. These ponds were fertilized with 12-5-5, inorganic fertilizer, but when water blooms failed to control the submerged vegetation, sodium arsenite or copper sulfate was occasionally used for this purpose.

Bluegill-bass ratios varying from 8:1 to 15:1 were used. Inventories of ponds showed that approximately 199 pounds of edible fish per acre could be produced annually in well managed ponds at Leetown regardless of the stocking ratio employed. The average size of bluegills varied inversely with the number stocked. The smallest bluegills, produced in the 15:1 bluegill-bass ratio, averaged about 5.7 inches in fork length, compared with about 6.5 inches from the 8:1 ratio. Largemouth bass failed to make good growth in the 15:1 ratio, averaging only 9.3 inches compared with 10.2 inches in the 8:1 ratio.

The fact that in two ponds 71 percent of the largemouth black bass in the original stocking were removed during a brief period suggests that good pond management may include removal of the fish in the same ratio as the original stocking, to assure maintenance of a balance of species.

INTRODUCTION

More than 30 years ago, Dyche (1914) made some interesting calculations on the amount of food required to feed 100 black bass in a farm pond. At 1 ounce per day for 30 days, he calculated that 100 bass would consume 187.5 pounds of fish. He did not think it possible for a 1-acre pond to produce such an amount of food. On the other hand, he pointed out that if adult sunfish did not eat their own kind, such an enormous number of fish are hatched that "if all lived and grew any size the water would soon become a solid mass of fish." He observed that the black bass fed extensively upon sunfish and that sunfish in turn devoured bass eggs when a bass was caught or driven off the spawning bed. It is interesting to find in his publication the statement that, "If you desire to raise black bass, and the bass are known to eat young crappies and sunfish, they can all be placed in the same pond, the old crappie and sunfish producing thousands of young which may serve as food for the bass under such circumstances; provided, further that the yearling sunfish do not eat up

the bass fry." Dyche observed that bluegills began spawning in June and spawned throughout the summer. He also noted that sunfish are cannibalistic when food grows scarce—a fact that recent studies have not yet borne out, but which certainly must be true. In a recent experiment with DDT (results unpublished) Mrs. D. D. Friddle and the writer had difficulty in keeping two sizes of bluegills together in aquaria because the larger fish ate the smaller ones.

In their efforts to find an association of two or three game and food fishes, which might live together and give a more complete utilization of the food in the farm pond, Barney and Canfield (1922) succeeded in increasing the standing crop of fish in their experimental pond to as high as 374 pounds, 11 ounces per acre. At the conclusion of their experiments in 1921 they observed that the ponds were still overstocked, although the number of fish had been reduced from 3,894 to 600 per acre. In earlier studies they used adult largemouth bass, sunfish, and crappies as well as fingerling bluegills and bass. In the final year of experimentation, they stocked only bluegills at the rate of 600 per acre, but continuous reproduction of the species prevented attainment of a good yield of edible fish.

These early studies have been followed by those of Swingle and Smith (1942), who determined how to stock and fertilize a farm pond in such a manner that yields of edible fish up to about 400 pounds per acre could be obtained.

This report includes the results of farm-pond experiments conducted at the Fisheries Experimental Station, Leetown, West Virginia, during the period 1943 through 1946. The objective has been to determine the production of edible fish from ponds in this latitude, with different stocking procedures. The size of the Leetown ponds varies from 0.29 to 1.47 acres; they are supplied with hard water from several springs which originate in limestone soils.[1]

Methods

All ponds have been stocked with bluegills and largemouth black bass, wintered over from the preceding season except in 1943 when fingerling bass of the year were used. Fingerling bluegills ranged from 1.7 to 2.9 inches long; fingerling bass carried over the winter were 1.9 to 3.5 inches, and fingerlings of the year ranged from 1.0 to 1.3 inches.

The average percentage of survival for bluegills stocked in these ponds was 86.3; the range was 73.3 to 100.0 percent. The mean survival for largemouth black bass was only slightly lower—83.0 percent—and ranged from 69.2 to 100.0 percent.

All fish were weighed after draining in a net for 45 seconds. Minimum lengths of "edible" fish were set arbitrarily as follows: largemouth black bass, 9 inches; bluegill, 5 inches; white crappie (*Pomoxis annularis*), 6.5 inches. Average fork lengths are based on random samples of 100

[1] The methyl-orange alkalinity of the water supply for these ponds is about 260 p.p.m.; the total hardness is about 280 p.p.m. as calcium carbonate.

specimens where they were available. Fingerling bluegills were sorted by means of wire-cloth screen graders, with two and three meshes to the inch (Fig. 1). Fish were dipped in 3-percent salt solution just before they were weighed.

Some of the ponds were opened for fishing as soon as the largemouth black bass attained a length of 9 inches. By this time the bluegills in most

FIGURE 1.—Wire-cloth screen grader used for sorting fingerling bluegills.

ponds were 5 inches or more in length. During the 1944 season, fishing was permitted in Pond F-5 between September 17 and October 18, and in Pond C-3 from September 22 to October 22. During 1946 all ponds were opened to fishing from July 27 to October 17, but fishing was not intensive on any pond except F-5.

In these experiments, inorganic 12-5-5 fertilizer [2] was used in all ponds except Ponds C-8 and C-9 during the 1945–1946 period. This fertilizer was applied at the rate of 100 pounds per acre per application.

Where fertilization failed to control the coarse plants, they were destroyed with sodium arsenite or copper sulfate. The numbers of chemical

[2] One hundred pounds of 12-5-5 inorganic fertilizer is composed as follows: 60 pounds ammonium sulfate (20.5 percent N); 25 pounds superphosphate (20 percent P_2O_5); 10 pounds muriate of potash (50 percent K_2O); 5 pounds filler.

treatments for weed control, and fertilizer applications for the various ponds are given in Tables 1 and 2.

TABLE 1.—*Number of treatments for destruction of aquatic weeds, and number of applications of fertilizer in the experimental farm ponds, 1943–1944*

[Fertilizers were applied each time at the rate of 100 pounds per acre]

Item	Year	Number of treatments or applications in pond								
		F-4	F-5	C-4	F-3	C-3	C-9	C-10	C-8	G-2
Treatment with copper sulfate....	1943	1	1	1	1	1	1	2	1	..
	1944	..	..	..	..	..	..	..	..	..
Treatment with sodium arsenite...	1943	..	..	..	..	..	..	..	..	1
	1944	1	..	1	1	..	1	1	..	1
Applications of 12–5–5 fertilizer...	1943	6	7	7	6	5	6	6	6	..
	1944	5	5	5	5	5	5	5	5	4

TABLE 2.—*Number of treatments for destruction of aquatic weeds, and number of applications of fertilizer in the experimental farm ponds, 1946*

[Fertilizers were applied each time at the rate of 100 pounds per acre]

Item	Number of treatments or applications in pond						
	C-8	C-9	C-10	F-3	F-4	C-3	F-5
Treatment with copper sulfate.....	1	1	..	1	..	1	1
Treatment with sodium arsenite.....	..	..	2	1	2	..	2
Applications of 12-5-5 fertilizer.....	..	..	5	5	5	5	5

YIELDS AT DIFFERENT STOCKING RATES

In the series of experiments initiated in June 1943 and concluded in the fall of 1944 (Tables 3, 4), an 8:1 ratio of bluegills and largemouth black bass was compared with a 10:1 ratio. Production of edible fish varied from about 165.1 to 275.3 pounds per acre. The principal difference in results from the two stocking rates lay in the size of the adult fish removed at the time of draining the ponds. Largemouth bass and bluegills were larger in the ponds with the smaller stocking ratios than in the ones with the higher stocking ratios. In the 1943–44 series of experiments, white crappies (Table 5) and brown bullheads (*Ameiurus n. nebulosus*) were used (Table 3) without marked effect on the net production of edible fish per acre. White crappies failed to make outstanding growth and to increase the production of edible fish. Specimens of the latter are illustrated in Figure 2 with bluegills about the same size. The very small brown bullheads stocked in Pond C-8 disappeared completely. Since they were only 0.7 inch long, it is presumed that they were consumed by the fingerling largemouth bass stocked at about the same time. The standing crop of fish produced in this series of experiments was generally high, ranging

TABLE 3.—*Number, weight, and size of fish produced in ponds stocked at the rate of 80 largemouth bass and 640 bluegills per acre, 1943–1944*

Species	Size classification at harvesting	Length range (inches)	Average length (inches)	Number per acre[1]	Weight[1] per acre (pounds)	Edible fish per acre[1] (pounds)
Pond F–4 (0.43 acre; stocked June 1, 1943; harvested November 1–2, 1944)						
Largemouth bass	Adult	11.4–13.1	11.9	79	78.6	78.6
do.	Fingerling	1.9– 2.8	2.3	1,351	6.5	.....
Bluegills	Adult	6.4– 7.5	6.9	672	196.7	196.7
do.	Yearling	4.0– 5.4	4.7	98	8.1	.....
do.	Fingerling	1.6– 4.6	2.6	10,407	118.4	.....
do.	do.	0.9– 1.9	1.6	8,605	21.6	.....
Totals	.....	.....	....	21,212	429.9	275.3
Pond F–5 (0.65 acre; stocked June 1, 1943; harvested November 2–3, 1944)						
Largemouth bass	Adult	9.4–12.0	10.8	80[1]	47.7	47.7
do.	Fingerling	2.0– 3.3	2.4	108	6.6	.....
Bluegills	Adult	6.3– 7.6	6.8	486[1]	141.8	141.8
do.	Fingerling	1.7– 4.1	2.6	13,235	173.7	.....
do.	do.	1.5– 2.1	1.8	2,466	7.7	.....
Totals	.....	.....	....	16,375	377.5	189.5
Pond C–8 (0.33 acre; stocked June 5, 1943; harvested October 25, 1944)						
Largemouth bass	Adult	10.8–12.1	11.5	55	43.9	43.9
do.	Fingerling	2.3– 3.8	2.6	1,006	7.9	.....
Bluegills	Adult	5.6– 7.0	6.3	518	104.8	104.8
do.	Fingerling	1.9– 4.5	2.4	15,067	139.4	.....
do.	do.	0.9– 2.3	1.6	2,297	6.4	.....
Brown bullheads[2]	(No harvest)	.....	....	.....	.....	.....
Totals	.....	.....	....	18,943	302.4	148.7

[1] Includes fish taken by angling prior to drainage in pond F–5
[2] Brown bullheads stocked in C–8 at rate of 100 per acre

from 181.9 pounds per acre to a maximum of 428.5 pounds per acre. Of particular interest was the removal of largemouth black bass from Pond F-5 (Figure 3) by angling. Here 71 percent of the largemouth bass and 48 percent of the bluegills in the original stocking were captured with hook and line. These fish were removed within a 49-day period after the pond was opened to fishing.

Again during 1946, in Pond C-8 (Table 6), 71 percent of the largemouth black bass and 14 percent of the bluegills were removed during a 55-day period of angling. In both ponds, more than 50 percent of the bass from the original stocking were removed, but in Pond F-5, the ratios of black bass to bluegills in the catch and in the original stocking were nearly the same. The fact that such a large number of largemouth bass could be removed in a short length of time suggests that good pond management might include the systematic removal of fish in the same ratio as in the original stocking.

In the second series of experiments beginning in July 1945, and ending

FIGURE 2.—Sample of largemouth bass, white crappies, and bluegills from Pond C-10, August 31, 1944.

FIGURE 3.—Farm pond F-5, August 31, 1944.

TABLE 4.—*Number, weight, and size of fish produced in ponds stocked at the rate of 100 largemouth bass and 1,000 bluegills per acre, 1943–1944*

Species	Size classification at harvesting	Length range (inches)	Average length (inches)	Number per acre[1]	Weight[1] per acre (pounds)	Edible fish per acre[1] (pounds)
Pond C–4 (1.47 acre; stocked June 5, 1943; harvested September 16, 1944)						
Largemouth bass	Adult	8.5–10.8	10.0	74	35.5	35.5
Bluegills	do.	5.1– 7.4	6.1	847	139.6	139.6
do.	Fingerling	2.0– 4.3	2.7	3,269	46.2	.....
do.	do.	1.0– 1.7	1.3	22,488	43.6	.....
do.	do.	.....	....	4,082	7.1	.....
Totals	.....	.....	....	30,760	272.0	175.1
Pond F–3 (0.36 acre; stocked June 1, 1943; harvested October 30, 1944)						
Largemouth bass	Adult	11.0–12.0	11.5	75	59.0	59.0
do.	Fingerling	2.9– 5.6	3.8	350	9.2	.....
Bluegills	Adult	4.8– 6.3	5.5	703	89.8	89.8
do.	Fingerling	1.8– 3.0	2.1	8,494	47.2	.....
do.	do.	1.1– 2.0	1.7	13,333	25.0	.....
Brown bullheads	Adult	8.8–10.1	9.3	222	73.1	73.1
do.	Fingerling	1.3– 1.9	1.6	1,461	3.4	.....
Totals	.....	.....	....	24,638	306.7	221.9
Pond C–3 (0.71 acre; stocked June 1, 1943; harvested October 27, 1944)						
Largemouth bass	Adult	8.9– 9.9	9.3	75	29.7	29.7
do.	Fingerling	3.4– 5.5	4.5	31	1.4	.....
Bluegills	Adult	5.1– 6.8	5.9	806	135.4	135.4
do.	Fingerling	1.0– 4.1	2.4	439	3.1	.....
do.	do.	0.8– 1.7	1.1	38,159	28.6	.....
Totals	.....	.....	....	39,266	198.2	165.1
Pond G–2 (0.48 acre; stocked October 2, 1943; harvested November 6, 1944)						
Largemouth bass	Adult	7.4–10.0	8.6	94	29.6	12.8
Bluegills	do.	4.9– 6.3	5.5	1,000	99.4	99.4
do.	Yearling	3.6– 4.9	4.2	775	36.5	.....
do.	Fingerling	1.2– 4.1	2.5	352	4.8	.....
Brown bullheads[2]	Adult	8.1– 9.8	9.0	33	11.5	11.5
Totals	.....	.....	....	2,254	181.8	123.7

[1] Includes fish taken by angling prior to drainage in pond C–3
[2] Bullheads present apparently survived previous draining, in puddles or mud

in October 1946, three stocking rates were tried. Two ponds were stocked with 50 largemouth black bass and 500 bluegills per acre (Table 6). Weeds were kept under control with either copper sulfate or sodium arsenite, but no fertilizer was used. Standing crops in these ponds were 219.5 and 305 pounds per acre. Net production of edible fish was 128.5 pounds per acre in one pond and 171.4 pounds in the second pond. Three ponds were each stocked with 100 largemouth black bass and 800 bluegills per acre (Table 7) and three ponds with 100 largemouth bass, and 1,500 bluegills per acre (Table 8). These ponds were fertilized with 12-5-5

TABLE 5.—*Number, weight, and size of fish produced in ponds stocked at the rate of 50 largemouth bass, 700 bluegills, and 300 white crappies per acre, 1943–1944*

Species	Size classification at harvesting	Length range (inches)	Average length (inches)	Number per acre	Weight per acre (pounds)	Edible fish per acre (pounds)
Pond C–10 (0.38 acre; stocked June 1, 1943; harvested October 24, 1944)						
Largemouth bass	Adult	11.9–12.5	12.2	40	37.9	37.9
do.	Fingerling	2.4– 3.4	2.8	1,232	11.3	.....
Bluegills	Adult	6.0– 7.8	6.4	650	124.7	124.7
do.	Fingerling	2.1– 4.1	2.9	15,324	216.6	.....
do.	do.	1.3– 2.2	1.7	3,687	10.8	.....
White crappies	Adult	5.6– 9.0	6.3	247	27.2	23.5
Totals	.....	.....	....	21,180	428.5	186.1
Pond C–9 (0.29 acre; stocked June 1, 1943; harvested September 9, 1944)						
Largemouth bass	Adult	10.6–11.6	11.1	38	27.2	27.2
do.	Fingerling	1.6– 5.0	2.1	290	1.7	.....
Bluegills	Adult	5.4– 6.6	6.0	628	126.9	126.9
do.	Fingerling	2.9– 4.4	3.3	1,672	51.7	.....
White crappies	Adult	6.0– 7.5	7.0	172	21.2	21.2
Totals	.....	.....	....	2,800	228.7	175.3

TABLE 6.—*Number, weight, and size of fish produced in ponds stocked at the rate of 50 largemouth bass, and 500 bluegills per acre, 1945–1946*

Species	Size classification at harvesting	Length range (inches)	Average length (inches)	Number per acre[1]	Weight[1] per acre (pounds)	Edible fish per acre[1] (pounds)
Pond C–8 (0.33 acre; stocked July 30, 1945; harvested October 26, 1946)						
Largemouth bass	Adult	11.5–11.8	11.6	48	36.3	36.3
Bluegills	do.	5.2– 7.5	6.4	367	92.2	92.2
do.	Yearling	1.4– 2.3	1.6	14,076	54.6	.....
do.	Fingerling	0.8– 1.5	1.0	72,727	36.4	.....
Totals	.....	.....	....	87,218	219.5	128.5
Pond C–9 (0.29 acre; stocked July 30, 1945; harvested October 23, 1946)						
Largemouth bass	Adult	11.5–13.0	12.0	42	35.4	35.4
Bluegills	do.	6.2– 7.5	6.7	493	136.0	136.0
do.	Yearling	3.5– 4.8	4.2	834	48.3	.....
do.	Fingerling	1.3– 2.1	1.6	17,931	44.8	.....
do.	do.	0.9– 1.6	1.0	57,490	40.5	.....
Totals	.....	.....	....	76,790	305.0	171.4

[1] Includes fish taken by angling prior to drainage in ponds C–8 and C–9

inorganic fertilizer at 100 pounds per acre (Table 2). There was no significant difference between the weights of edible fish produced per acre in these two series of fertilized ponds. In the fertilized ponds standing crops ranged from 263 to 342.1 pounds, and edible fish varied between

TABLE 7.—*Number, weight, and size of fish produced in ponds stocked at the rate of 100 largemouth bass, and 800 bluegills per acre, 1945–1946*

Species	Size classification at harvesting	Length range (inches)	Average length (inches)	Number per acre[1]	Weight[1] per acre (pounds)	Edible fish per acre[1] (pounds)
Pond C–10 (0.38 acre; stocked July 30, 1945; harvested October 31, 1946)						
Largemouth bass	Adult	9.5–10.8	10.1	82	43.5	43.5
do.	Fingerling	2.3– 5.7	4.4	224	15.1	.....
Bluegills	Adult	5.8– 7.5	6.6	642	142.6	142.6
do.	Yearling	1.0– 1.7	1.4	15,526	38.8	.....
do.	Fingerling	1.1– 1.5	1.3	17,718	23.0	.....
Totals	.....	.....	....	34,192	263.0	186.1
Pond F–3 (0.36 acre; stocked with bluegills July 23, 1945, with bass August 3, 1945; harvested October 17, 1946)						
Largemouth bass	Adult	9.9–11.3	10.6	19	35.8	35.8
Bluegills	do.	5.3– 7.5	6.5	578	162.9	162.9
do.	Yearling	1.8– 4.6	3.4	828	23.3	.....
do.	Fingerling	0.6– 1.5	1.0	450,072	106.3	.....
Totals	.....	.....	....	451,497	328.3	198.7
Pond F–4 (0.43 acre; stocked with bluegills July 23, 1945, with bass August 3, 1945; harvested October 18, 1946)						
Largemouth bass	Adult	7.8–10.5	9.8	42	42.5	39.0
Bluegills	do.	5.5– 7.3	6.3	607	163.9	153.2
do.	Fingerling	.....	....	138,372	69.2	.....
Totals	.....	.....	....	139,021	275.6	192.2

[1] Includes fish taken by angling prior to drainage in ponds, C–10, F–3, F–4

186.1 and 233.7 pounds per acre.

In those ponds stocked with 1,500 bluegills per acre the largemouth black bass and bluegills averaged smaller, 9.3 and 5.7 inches respectively, than those stocked with 100 largemouth bass and 800 bluegills per acre, where average lengths were 10.2 and 6.5, respectively.

No significant difference was found in the production of edible fish resulting from the various combinations (Table 9). The average production for all ponds was 199 pounds per acre. It should be pointed out, however, that the largemouth bass and bluegills produced at the lower stocking ratio of 100 bass and 800 bluegills per acre are more desirable (larger) than those at the higher stocking rates.

Comparison with Production in Other Waters

In this series of experiments, standing crops reached a maximum of 428 pounds per acre in one pond and nearly half of the ponds had standing crops exceeding 300 pounds per acre. The ponds with the largest standing crops were those with the greatest weights of undersized bluegills. These were ponds where the young bluegills received greatest protection

from submerged larger aquatic plants which were not controlled completely.

In his studies of the fish population in 24 ponds, Bauman (1946) found standing crops varying from 35.9 to 376.7 pounds per acre. Fish of edible size in these ponds ranged from 1.63 to 21.75 pounds per acre. In Fork Lake, Illinois, Bennett, Thompson, and Parr (1940) obtained during the 1939 season a yield of 934 fish or 162 pounds per acre through removal of fish by angling at the rate of 25 pounds per acre per month. They estimated that this production was half of the theoretical carrying capacity of the lake for hook-and-line fish. Bennett (1945) recorded a hook-and-line yield of 349.95 pounds of fish in Onized Lake, Illinois, in 1939. Other

TABLE 8.—*Number, weight, and size of fish produced in ponds stocked at the rate of 100 largemouth bass and 1,500 bluegills per acre, 1944–1946*

Species	Size classification at harvesting	Length range (inches)	Average length (inches)	Number per acre[1]	Weight[1] per acre (pounds)	Edible fish per acre[1] (pounds)
Pond F–5 (0.65 acre; stocked with bluegills July 23, 1945, with bass August 3, 1945; harvested October 24, 1946)						
Largemouth bass	Adult	8.8–10.2	9.5	51	35.6	34.6
do.	Fingerling	5.5– 6.0	5.8	6	1.2	.....
Bluegills	Adult	4.9– 6.2	5.7	1,203	207.3	199.1
do.	Yearling	1.3– 3.1	1.7	26,325	84.6	.....
do.	Fingerling	0.6– 1.1	0.8	169,909	63.4	.....
Totals	.....	.....	....	197,494	392.1	233.7
Pond G–1 (0.90 acre; stocked June 13, 1944; harvested August 1, 1945)						
Largemouth bass	Adult	8.5–11.5	9.0	89	37.0	12.5
Bluegills	do.	5.0– 6.0	5.6	1,354	191.5	191.5
do.	Yearling	2.4– 4.1	3.1	299	30.7	.....
do.	Fingerling	0.6– 1.4	0.8	59,840	27.6	.....
Totals	.....	.....	....	61,582	286.8	204.0

[1]Includes fish taken by angling prior to drainage in pond F–5

Illinois lakes had high fish production ranging around 400 pounds per acre. Swingle and Smith of Alabama in numerous papers have reported yields of 400 to 600 pounds of edible fish per acre in Alabama ponds. These production figures may be contrasted sharply with Westerman and Hazzard's (1946) figures for 18 Michigan lakes in which the fish were poisoned to permit restocking with a more desirable species. These lakes averaged 69 legal-sized game fish per acre. Westerman and Hazzard pointed out that creel censuses of a number of Michigan lakes show 36 adult fish caught per acre per year.

Over a 4-year period at the Tulsa Hatchery, Aldrich (1943) observed that he was able to produce on the average, 180 pounds of bluegills per acre. The 4-year average production in number per acre was 32,392. He observed that it was not unusual to produce 100,000 1-inch bluegills per acre.

TABLE 9.—*Production of edible fish in fertilized farm ponds with different stocking combinations*

Number per acre		Pounds per acre			Mean pounds per acre
Largemouth bass	Bluegill	Individual ponds			
80	640	275	190	149	205
100	800	186	199	192	192
100	1,000	175	222	165	187
100	1,500	234	204		219

Studies at Leetown indicate that 100 largemouth black bass and 800 bluegills per acre in this latitude will be adequate to produce good fishing in fertilized farm ponds. With the lower stocking rate, the size of the fish taken by angling should be very desirable, and there should be less likelihood of overpopulation with small bluegills.

The evidence collected to date indicates that only approximately one-half of the production of edible fish obtained in the deep South can be obtained in the Leetown ponds. This difference may be due to the considerably shorter growing season.

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THE NIACIN AND BIOTIN REQUIREMENT OF TROUT

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ABSTRACT

Brook, brown, and rainbow trout were fed diets containing various levels of niacin and biotin. After a period, trout were killed and their livers analyzed for the vitamin content. The diet level of the vitamin causing maximum storage in the liver was considered as the tentative requirement of the trout. The requirement for niacin was found to be between 3.0 and 4.1 milligrams per kilogram of trout daily. Maximum storage was between 34 and 38 micrograms per gram of liver. There was no difference in requirement between species or the two temperatures of the experiment. There was a difference between species in their requirement for biotin. Brook and rainbow trout needed between 6,700 and 26,880 milli-micrograms per kilogram of weight and brown trout between 43,360 and 76,980 milli-micrograms. Temperature of the experiment had no effect upon the requirement. Maximum storage was approximately 1,100 milli-micrograms per gram of liver in brown trout and about 1,200 milli-micrograms for brook and rainbow trout.

INTRODUCTION

The requirement of trout for niacin (nicotinic acid) and biotin were studied during the summer of 1947 as a continuation of the vitamin experiments started at the Cortland laboratory in 1944. Six of the B vitamins have now been investigated including, in addition to niacin and biotin, pantothenic acid, riboflavin, thiamin and pyridoxine (Tunison *et al.*, 1944; Phillips, 1949).

In a previous report (Phillips, 1949) the general problem of the vitamin requirement of fish has been discussed together with methods employed in such studies. The reader is referred to this paper for a review of the literature on these subjects.

METHODS

The method employed for these experiments was similar to that previously described (Phillips, 1949). Diets containing graded levels of niacin and biotin were fed to brook, brown, and rainbow trout.[1] After a period

[1] *Salvelinus fontinalis, Salmo trutta, Salmo gairdnerii irideus.*

of approximately 8 weeks, samples of trout were killed and their livers were analyzed for vitamin content. It was possible by this method to determine which dietary level of the vitamin resulted in a maximum storage in the liver of the fish. This level was taken as the tentative requirement of the trout.

The experiments were run at two water temperatures (47° and 52° F.). Two series of analyses were made about 2 months apart. The experiments were started in mid-April and concluded in early September.

The diets employed and the levels of the vitamins fed are shown in Table 1. Fish were handled according to the established procedure of this laboratory (Tunison *et al.*, 1939) and were fed at a uniform rate of 6 percent of their body weight per day during the experimental period.

Niacin was determined by the micro-biological assay method of Snell and Wright (1941) and biotin by the method of Wright and Skeggs (1944) as modified by Williams (1945). The test organism in both methods was *Lactobacillus arabinosus*. Three determinations were made upon pooled liver samples from trout of each experimental trough at the two time intervals (series) of the experiment.

The amount of vitamin present in the diet (Table 1) was established by a series of preliminary analyses. It was found that the beef liver contained 97 micrograms of niacin per gram and the beef spleen 33 micrro-

TABLE 1.—*The percentage composition of experimental diets, the vitamin content, and the amounts fed to fish daily*

Diet number	Beef spleen (percentage)	Beef liver (percentage)	Salt (percentage)	Niacin		Biotin	
				Micrograms per gram of diet	Milligrams fed per kilogram fish	Milli-micrograms per gram of diet	Milli-micrograms fed per kilogram fish
1	....	98.0	2.0	95.0	5.7	1,283	76,980
2	40.0	58.0	2.0	69.0	4.1	806	43,360
3	70.0	28.0	2.0	50.0	3.0	448	26,880
4	98.0	....	2.0	32.0	1.9	113	6,780

grams per gram. Waisman and Elvehjem (1941) in a summary of the literature gave the range of niacin in beef liver as 92 to 186 micrograms per gram and in beef spleen as 44 to 53 micrograms per gram. Dann and Handler (1942) found the niacin content of beef liver to be 100 micrograms per gram. Our results are, therefore, in reasonable agreement with those of previous workers. They represent an average of 10 analyses for each food and their consistency warrants their use in establishing the dietary levels. The values determined for biotin were 1,310 milli-micrograms per gram for beef liver and 115 milli-micrograms for beef spleen. These compare favorably with those of Sweigert *et al.* (1943). Results of

experiments were tested statistically by analyses of variance upon a split-plot design. Appreciation is expressed to Dr. C. M. Mottley for his assistance in the statistical procedure.

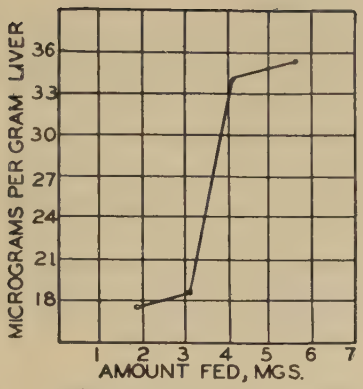
The Niacin Requirements of Trout

The level of niacin stored in the liver of the trout varied directly with that present in the diet up to a maximum beyond which additional dietary vitamin did not increase the liver storage (Table 2). These results agree

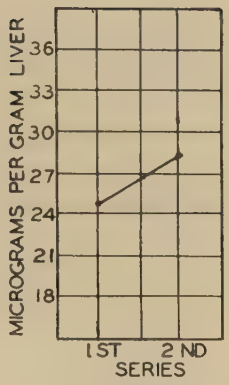
Table 2.—*Vitamin storage in livers of trout fed diets with varying quantities of niacin*

Diet number	Species of trout	First series		Second series	
		Average weight of fish (grams)	Micrograms of niacin per gram of fish liver	Average weight of fish (grams)	Micrograms of niacin per gram of fish liver
	Water temperature, 47°F.				
1	Brook	5.4	31.1	12.2	37.0
2	do.	5.3	30.0	12.6	38.0
3	do.	4.7	11.6	10.7	18.6
4	do.	4.2	12.3	7.5	19.0
1	Brown	1.7	33.4	3.5	34.0
2	do.	1.8	34.0	3.5	33.3
3	do.	1.8	20.1	3.4	19.0
4	do.	1.6	15.9	3.4	18.6
1	Rainbow	5.3	32.7	9.0	36.0
2	do.	5.5	33.1	8.3	32.0
3	do.	5.1	12.6	7.9	19.0
4	do.	5.1	14.6	7.5	19.0
	Water temperature, 52°F.				
1	Brook	7.1	33.4	15.5	38.3
2	do.	6.7	28.1	14.5	32.6
3	do.	5.2	15.9	10.2	19.6
4	do.	6.5	13.1	12.0	21.0
1	Brown	2.7	34.6	5.6	39.6
2	do.	2.5	35.3	4.7	39.0
3	do.	2.1	22.4	4.3	21.6
4	do.	1.9	22.1	3.0	21.6
1	Rainbow	6.7	32.3	12.3	35.3
2	do.	5.4	33.5	9.2	39.6
3	do.	5.6	15.8	7.6	20.0
4	do.	5.4	16.0	7.9	19.7

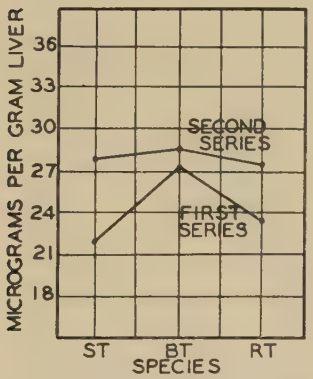
with those reported previously for the other vitamins studied (Tunison *et al.*, 1944; Phillips, 1949). There was no difference in maximum storage among the three species of trout, but there was a greater storage in all three species at the time of the second series of analyses. Maximum storage in the livers was approximately 34 micrograms of niacin per gram of fish liver at the time of the first series and about 38 micrograms per gram during the second series. This difference may be a function of age, fish size, or some other unmeasured factor. Dann and Handler (1942) reported comparable levels of niacin (38 micrograms per gram) in trout muscle.



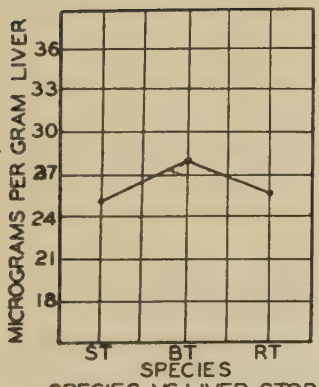
AMOUNT FED VS. LIVER STORAGE



TIME VS. LIVER STORAGE



SPECIES VS. LIVER STORAGE
THE TWO SERIES COMPARED



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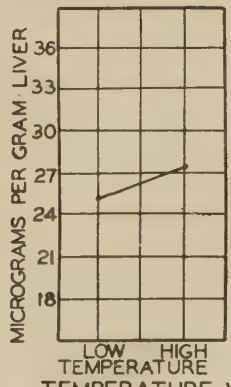

TEMPERATURE VS. LIVER STORAGE

FIGURE 1.—Results of experiments with niacin. ST = brook trout; BT = brown trout; RT = rainbow trout.

Since maximum storage of niacin resulted when 3.0 to 4.1 milligrams were fed per kilogram of body weight, this quantity is taken as the tentative requirement of trout.

The Biotin Requirement of Trout

As was found with all the B vitamins studied, biotin storage in the liver of trout reflects the amount present in the diet up to a point of maximum storage (Table 3). Unlike any of the others, however, there was a difference in maximum storage between species as well as between series of analyses. Brook and rainbow trout stored approximately 1,200 milli-micrograms per gram of liver and brown trout about 1,100 milli-micrograms

Table 3.—*Vitamin storage in livers of trout fed diets with varying quantities of biotin*

Diet number	Species of trout	First series		Second series	
		Average weight of fish (grams)	Milli-micrograms of biotin per gram of fish liver	Average weight of fish (grams)	Milli-micrograms of biotin per gram of fish liver
	Water temperature, 47°F.				
1	Brook	8.1	1,254	14.4	1,276
2	do.	7.9	1,281	15.3	1,387
3	do.	6.7	1,300	12.3	1,346
4	do.	5.1	857	8.9	901
1	Brown	2.4	1,134	3.8	1,339
2	do.	2.5	996	3.9	1,160
3	do.	2.3	735	3.4	850
4	do.	2.3	630	3.7	851
1	Rainbow	6.6	1,114	11.0	1,420
2	do.	6.6	1,173	8.8	1,300
3	do.	5.8	1,210	8.2	1,197
4	do.	5.7	697	7.9	836
	Water temperature, 52°F.				
1	Brook	10.5	1,226	18.9	1,373
2	do.	10.4	1,260	18.4	1,366
3	do.	7.2	1,258	11.9	1,173
4	do.	8.8	678	13.5	941
1	Brown	3.4	1,060	7.1	1,299
2	do.	4.0	974	5.6	1,114
3	do.	3.6	738	5.0	969
4	do.	2.5	647	3.4	889
1	Rainbow	9.3	1,337	15.5	1,372
2	do.	7.2	1,223	10.7	1,275
3	do.	5.7	1,285	7.7	1,296
4	do.	6.4	766	9.1	900

during the first series. At the time of the second series brook and rainbow trout produced a maximum storage of 1,300 milli-micrograms and brown trout 1,200 milli-micrograms per gram of liver. As was stated for niacin, this increase may be caused by difference in fish size, age, or some other variable.

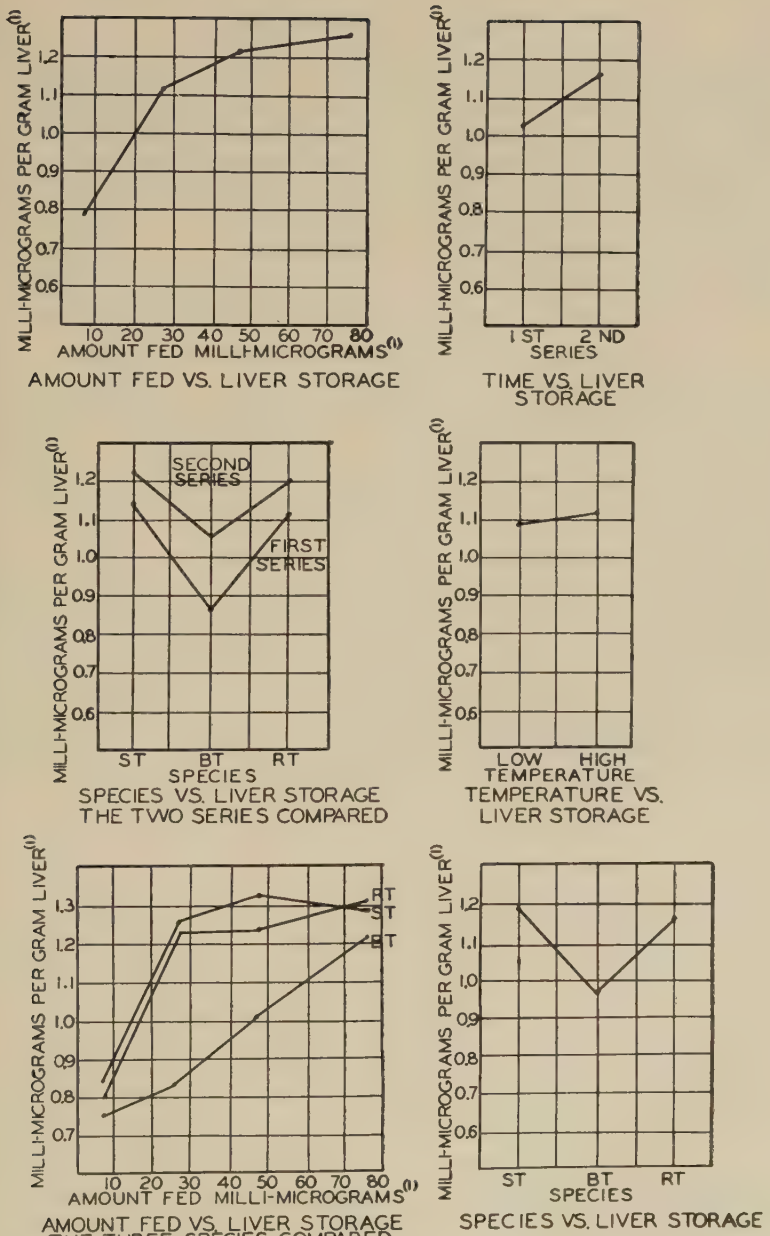

FIGURE 2.—Results of experiments with biotin. ST = brook trout; BT = brown trout; RT = rainbow trout. The vitamin units are expressed in thousands.

There was also a significant difference in the level of dietary vitamin required to cause maximum storage in the different species. Brown trout needed between 43,360 and 76,980 milli-micrograms of biotin per kilogram of body weight to attain maximum storage whereas brook and rainbow trout needed only 6,700 to 26,880 milli-micrograms of biotin daily to produce maximum storage. There was no difference in vitamin requirement at the two temperatures of the experiment.

Figure 2 shows graphically the major variables of the experiment.

Significance of the Experimental Results

During these studies, no pathological conditions were noted in fish receiving low levels of either biotin or niacin. As stated previously, however (Phillips, 1949), the only safe assumption is that the assumed requirements actually are needed until proved otherwise. It is possible to feed diets low in both of the vitamins if proper precautions are not taken in formulating the diet. To insure a safe level the standard recommendation of 10 to 15 percent of the diet as beef liver is suggested.

One of the most interesting results of these studies was the species difference found in the requirement for biotin. This difference is the first we have noted in our vitamin studies. If one such difference exists there may be many more that are yet unknown. These differences in nutrition may be the basis of the difficulties encountered in rearing different species of trout. Brown trout appear to be a likely experimental animal for further study along this line. Biotin itself is probably not a determining factor with these rearing difficulties, but the results obtained with it do suggest a different type of study than has been practiced in the past.

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EFFECTS OF SOME INSECTICIDES ON TROUT AND SALMON IN ALASKA, WITH REFERENCE TO BLACKFLY CONTROL [1]

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ABSTRACT

One of the important features of a research program on blackfly control in Alaska in 1947 was an investigation of the effects of several recently developed insecticides on fish inhabiting blackfly streams. Trough and stream experiments were conducted, with rainbow trout as the principal test species and utilizing also Dolly Varden trout, king salmon, silver salmon, and red salmon. DDT, benzene hexachloride, chlordan, and chlorinated camphene were the chief toxicants tested and were applied as xylene-Triton emulsions, acetone solutions, and, in some experiments, as fuel-oil solutions and Velsicol AR-50 solutions. Blackfly larvae and other stream-bottom organisms were tested with the fish in both trough tests and in stream treatments. The minimum lethal concentrations for most of the chemicals were determined in the troughs for the three groups of organisms, and margins of safety between blackfly larvae and fish and fish-food animals were tested in the stream.

DDT in acetone solution and fuel-oil solution, chlordan in acetone solution and fuel-oil solution, and toxaphene in acetone solution showed some promise as effective blackfly toxicants likely to be safe for fish and fish foods.

Stomach-content analyses showed blackfly larvae to represent 1.8 percent by weight of the total contents of trout and salmon examined, and their loss as fish food is not considered as serious in the area studied.

INTRODUCTION

In recent years there has developed much interest in treatment of natural waters with poisons for the purpose of eradicating various kinds of organisms, including weeds, noxious insects, and undesirable fishes. A definite

[1] This work was conducted by the U. S. Department of Agriculture, Agricultural Research Administration, Bureau of Entomology and Plant Quarantine, under a transfer of funds from the Office of the Surgeon General, Department of the Army, and, in part, from the Bureau of Medicine and Surgery, Department of the Navy, to the Bureau of Entomology and Plant Quarantine.

extension of activity within the field of medical entomology has encouraged the development of new, more toxic insecticides. The chlorinated hydrocarbons, in particular, have been investigated for toxic properties, and many such products have been marketed in the past few years in several forms. Since DDT first came into widespread use for the control of mosquito larvae in the field, the ultimate fate of fresh-water fishes exposed to such insect-control measures has been a matter of concern to fishery interests. In the past, these control operations have been principally on shallow, still waters not supporting populations of fish of significance commercially or for sport. More recently, however, there have been movements on the part of entomologists toward the chemical control of blackflies through the treatment of the swiftly moving waters in which certain species of fly larvae develop. This action penetrates to the trout stream itself and immediately attracts attention to the matter of the consequences to salmonid fishes exposed to the toxicants. It was with possible drastic effects in mind that a study of some local fishes and their food was inaugurated in the summer of 1947 in connection with blackfly-control activities in central Alaska. The present paper reports the results of the fishery aspects of the first season's accomplishments; the presentation of the blackfly findings has appeared elsewhere. (Gjullin, *et al.*, 1949).

Some mention of damage to fish life during simuliid-control treatments has been made in the literature. Garnham and McMahon (1947) reported extensive mortality to fish in Kenya after DDT-emulsion applications for the eradication of blackflies, but gave no information concerning the species of fish or the exact strengths causing death. Prévost (1946) wrote, "We succeeded in killing blackfly larvae by DDT without killing the fish". No specific facts concerning formulation or concentration of toxicant were imparted in this paper.

Aims of the Project

In this study emphasis was placed upon three principal aspects of the problem in order that indirect as well as direct consequences to fish life could be observed. In the ecological complex of streams featuring three species of anadromous fishes as well as some resident species of economic importance there exist many possibilities for damage through the introduction of poisons. Not only are the fish themselves vulnerable, but the various segments of their food chains are liable to damage. The times of occurrence of the organisms involved is another factor for consideration in a treatment program. The chief problems chosen for investigation, based on the foregoing points, were studies of (1) the toxicity of the chemicals to fish, (2) the toxicity of the chemicals to fish-food organisms, and (3) the place of blackfly larvae in the fish diet.

Facilities and Methods

The waters chosen for the testing were blackfly streams in the Anchorage, Alaska, area. Otter Creek, in which the majority of tests were con-

ducted, and out of which water was pumped for tests in hatchery troughs, represents the outflow from eutrophic, marl-bottomed Otter Lake. Otter Creek has an average width of 8 feet, an average depth of 6 inches, and had summer flows in 1947 of from 3.2 to 4.5 cubic feet per second. The pH of the water during this season varied from 7.3 to 8.4. The total alkalinity, which was all methyl-orange alkalinity, expressed in terms of calcium carbonate, varied from 75 to 120 p.p.m. Daytime water temperature ranged from 55° F. to 76° F., and dissolved-oxygen content fluctuated from 6.9 to 10.8 p.p.m.

In order to observe results in waters with properties different from those of Otter Creek, testing facilities were established on Rabbit Creek and Little Campbell Creek. These streams drain parts of the Chugach Range south of Anchorage and are principally spring-fed. Their waters exhibited temperatures of 42° F. to 50° F., pH readings of 7.5 to 7.6, and dissolved-oxygen values of 10.5 to 12 p.p.m. The flow of each of these streams was below 2 cubic feet per second, and their velocities ranged from 2 to 4 feet per second.

The faunae of these streams were not alike. Otter Creek provided test fishes of the following species: red salmon (*Oncorhynchus nerka*), silver salmon (*Oncorhynchus kisutch*), king salmon (*Oncorhynchus tsahawytscha*), rainbow trout (*Salmo gairdnerii*), Dolly Varden trout (*Salvelinus malma*), stickleback (*Gasterosteus aculeatus*), and a sculpin (*Cottus aleuticus*). The salmon were present as adults on spawning runs and as fingerlings on seaward migrations. Rabbit Creek and Little Campbell Creek support only limited fish faunae, with rainbow trout and Dolly Varden trout as the only kinds occurring in abundance. The bottom organisms of Otter Creek were considerably more plentiful both in numbers of individuals and numbers of species than were those in the smaller streams. The caddice genera *Hydropsyche, Brachycentrus,* and *Hesperophylax* were particularly well represented in Otter Creek. The mayfly genus *Ephemerella* was found in all three streams. The species of simuliids in these waters are discussed in the companion to this paper (Gjullin, *et al.,* 1949).

The physical facilities for testing were chosen for the prosecution of two types of procedure. It was desired at the outset to carry on some work at relatively high concentrations of toxicants without endangering the organisms in the stream. To accomplish this purpose a series of hatchery troughs was obtained from the Fort Richardson U. S. Engineers, who fabricated them to our specifications. For the second type of testing procedure, it was desired to conduct the work in the stream itself in order to duplicate as nearly as possible a practical control application. To meet this requirement, it was necessary to set off sections of the stream, measuring from 150 to 200 yards long, and to construct weirs for measuring stream flow.

The hatchery-trough installation consisted of a row of five parallel troughs, the upper ends of which received equal flow of water from a head trough placed at right angles to the testing troughs. Water was

pumped from Otter Creek into the head trough. After it passed through the screened tops of the batter boards in the testing troughs at the rate of 5 gallons per minute, it flowed through fire hoses to a pit remote from the stream. The chemicals were dispersed into the troughs from aspirator bottles through stop-cocks, and the flow was calibrated to give predetermined concentrations. The tests, involving rainbow trout, blackfly larvae, and caddicefly larvae, comprised a 15-minute treatment period and a 48-hour post-treatment phase. The selection of the 48-hour time was based on prior tests and on limitations in the amount of equipment. The fish swam freely in the troughs during treatment, while blackfly larvae were confined in fine-mesh screened containers, and caddicefly larvae were held in screened cages of another type. Ten fish and 10 caddicefly larvae were used in each trough, both for the treated waters and for the untreated controls. When treatment was ended, all animals were immediately placed in the stream for the holding period. Trout and caddicefly larvae were observed for 48 hours and notes were made on their condition.

All animals tested were collected from the creek, held for only short periods before treatment, and were selected for testing on the basis of condition and size.

The tests conducted in the streams were designed to follow the pattern of the trough tests which had preceded them. The same periods of time were used for treatment and post-treatment phases, and much of the same equipment was used in both trough and stream experiments. It was usually possible to observe fish swimming free in the stream, as well as those confined in live cars.

Several insecticides were used during the course of the work, and many were applied in several formulations. Most of our attention was devoted to the four organic toxicants listed in the paragraphs that follow.

DDT (dichloro diphenyl trichloroethane) was applied as an emulsion, as an acetone solution, as a fuel-oil solution in various strengths, as a kerosene solution, and as a 90-percent wettable powder.

Benzene hexachloride was applied as an emulsion and as an acetone solution, and was represented as 100-percent gamma isomer.

Chlordan (Velsicol 1068, $C_{10}H_6Cl_8$) was applied as an emulsion, as an acetone solution, as a fuel-oil solution, and as a solution in Velsicol AR-50.

Chlorinated camphene (Toxaphane, $C_{10}H_{10}Cl_8$) was applied as an emulsion, as an acetone solution, as a fuel-oil solution, and as a solution in Velsicol AR-50.

All the emulsions consisted of 25 percent of the toxicant, 10 percent Triton X-100, and 65 percent xylene. The acetone solutions contained 10 grams of the toxicant per liter.

Other substances tested on smaller scales were: pyrethrins in acetone mixture, pyrethrins in kerosene solution, Rutgers 612 repellent, dimethyl phthalate, dimethyl phthalate emulsion, indalone, Velsicol AR-50 solvent, fuel oil, and kerosene.

Toxicity of the Chemicals to Fish

Trough Tests.—In these tests, which were carried on at relatively high concentrations of toxicants, it was possible to recognize the comparative toxic effects of the substances used. The detailed data given in Table 1 show the differences, where they exist, between chemical strengths producing morbidity and those causing death.

The results indicate that DDT was the least toxic to fish of the four chemicals tested in running water. Chlordan proved to be slightly more toxic than DDT in both emulsion and acetone-suspension formulations. Chlorinated camphene was the second most poisonous insecticide in the two formulations tested. Benzene hexachloride was the most toxic of the chemicals in emulsion form and second in toxicity as an acetone suspension. These conclusions are based on the numbers of fish found dead at 24 and 48 hours. In these tests the concentrations producing disabling effects on trout at the end of the 15-minute tests were not consistently greater than the concentrations causing death at 24 and 48 hours, with one exception. Table 1, illustrating the differences in tolerance between emulsions and acetone suspensions, shows that 20 p.p.m. of chlorinated camphene suspension is required to render trout helpless in 15 minutes, while only 8 p.p.m. is needed to cause an appreciable number of deaths at 24 and 48 hours. This delayed action was displayed by no other chemical tested

Table 1.—*Comparison of effects of xylene-emulsion and acetone-solution formulations of four insecticides on rainbow trout*

Chemical	Formulation	Lowest tested strength (p.p.m.) disabling trout in 15 minutes	Lowest tested strength (p.p.m.) causing helplessness or death in 24 hours
DDT	Emulsion	8	12
	Acetone solution	35	35
Benzene hexachloride	Emulsion	1	1
	Acetone solution	10	15
Chlorinated camphene	Emulsion	8	5
	Acetone solution	20	8
Chlordan	Emulsion	5	5
	Acetone solution	30	30

and suggests agreement with the findings of Surber (1948), who reported extremely high toxicity for chlorinated camphene in standing water.

The toxic properties of emulsified toxicants, as compared with those of acetone suspensions of the same toxicants, are strikingly portrayed in Table 1. It may be pointed out that in every experiment, the emulsions were considerably more poisonous to trout than were the suspensions.

The influence of temperature on the action of the insecticides tested became noticeable when tests were conducted near the upper limit of

tolerance of the trout. In general, all chemicals were more toxic at higher temperatures, but the data of Table 2 indicate that occasionally higher toxicity was exhibited at low temperatures.

It is thought that some mortality at 24 and 48 hours was due to causes other than chemical treatment since some of the fish that died exhibited no symptoms of poisoning during treatment. Such causes as holding fish at high temperatures, holding in swift currents, or handling probably accounted for some of the kills listed in Tables 2 and 3 and partially explain higher kills after stream tests at given concentrations than at stronger concentrations of the same poison in troughs.

Stream Tests.—The results of the stream tests did not contribute information on the limits of tolerance of fish to the toxicants used. However, the numerous replications of experiments with various formulations at several low concentrations established the fact that the dosages of some of the toxicants required for effective blackfly control are well below the limits of tolerance of the fish tested. Table 5 indicates that several substances may be used safely, but that none has the wide margin of safety displayed by DDT in acetone. Other poisons with reasonable margins of safety are: chlordan in acetone; DDT in fuel oil; chlordan in fuel oil; chlorinated camphene in acetone, DDT emulsion, and DDT as a wettable powder. Benzene hexachloride in acetone solution, although showing a fairly safe margin, is considered dangerous to handle. The following substances are considered not practical for blackfly control in Alaska due to their high toxicities to salmonids and their food (Table 5): benzene hexachloride emulsion; chlorinated camphene emulsion; chlordan emulsion; and pyrethrins in acetone and kerosene.

Other Fish.—It was found that fingerlings of some other salmonids were almost exactly as susceptible to the actions of all the chemicals tested as were rainbow trout. Silver and king salmon fingerlings were tested in several experiments in both troughs and streams, and exhibited the same tolerance as the rainbow trout. Dolly Varden trout of the same size group were slightly more resistant to the action of emulsions than were rainbow trout. Red salmon fingerlings were difficult to test because of damage incurred during handling and holding. Mortality was so high in control live cars in tests with red salmon fingerlings that it was not possible to determine the effects of chemicals alone.

Adult silver, king, and red salmon in stream tests proved to be tolerant of low concentrations of some toxicants. Silver salmon adults showed no agitation at strengths up to 0.05 p.p.m. of DDT emulsion, 1 p.p.m. of chlordan emulsion, 1 p.p.m. of chlorinated camphene emulsion, and 0.1 p.p.m. of benzene hexachloride. These concentrations were the highest tested. Red salmon adults showed no bad effects from concentrations up to 0.5 p.p.m. of DDT emulsion, 1 p.p.m. of wettable DDT, 0.4 p.p.m. of DDT fuel-oil solution, 0.1 p.p.m. of benzene hexachloride emulsion, 1 p.p.m. of chlorinated camphene emulsion, and 1 p.p.m. of chlordan

TABLE 2.—*Toxicities of insecticides to rainbow trout and to caddicefly larvae in trough tests*

Formulation	Strength (p.p.m.)	Water temperature (°F.)	Rainbow trout			Caddicefly larvae[1]	
			Percentage helpless in 15 minutes	Percentage dead in 24 hours	Percentage control dead in 48 hours	Percentage of caddicefly larvae killed in 24 hours	
						Hydropsyche	*Hesperophylax*
DDT							
Emulsion	3	65	0	0	0	0	0
	5	61	0	0	0	0	0
	5	74	0	[2]10(20)	0	0	0
	8	64	20	0	0	100	10(40)
	12	75	100	70	0	0	0
	15	67	100	20	10	20	0
Acetone Solution	5	73	0	0	0	–	–
	10	70	0	0	0	0	0
	15	67	0	0	0	–	–
	15	72	0	0	0	–	0
	15	63	0	0	0	100	100
	20	68	0	0	0	100	100
	30	59	0	0	0	–	–
	35	67	0	10	0	–	–
Benzene hexachloride							
Emulsion	1	64	80	20	0	90	0
	3	65	100	100	0	80	40
	5	61	100	80	0	20(100)	0(90)
	5	72	100	100	0	–	–
	12	75	100	100	0	90(100)	30(100)
	15	67	100	100	10	100	100
Acetone Solution	10	70	10	0	0	0	0
	15	63	90	100	0	80	0(10)
	20	68	100	80(90)	0	80(100)	60(100)

TABLE 2.—(*Continued*)

Chlorinated camphene							
Emulsion.....	3	65	0	0	0	0	0
	5	60	0	0	0	10	0
	5	74	0	30	0	0	0
	8	64	50	10	0	20(80)	10
	12	75	100	70	0	20(100)	0
	15	67	100	80	10	60(100)	0
Acetone Solution...	5	59	0	0	0	–	–
	8	67	0	30	0	–	–
	10	70	0	0	0	20	0
	15	63	0	40	0	60(80)	0
	20	68	0	100	0	70(90)	0
Chlordan							
Emulsion.....	3	65	0	0	0	0(10)	0
	5	60	0		0	20	0
	5	72	30	40	0	–	–
	8	64	100	10	0	10(80)	0
	12	75	100	80	0	80(90)	40
	15	67	100	80	0	10(100)	0
Acetone Solution...	5	73	0	0	0	–	–
	10	59	0	0	0	–	–
	10	70	0	0	0	0	0
	15	63	0	0	0	80(100)	10(50)
	20	68	0	0	0	90(100)	20(40)
	30	67	30	30	0	–	–

[1] Controls are not listed in the table. No mortality occurred in caddicefly control cages
[2] 48-hour kill shown in parenthesis when it differs from the 24-hour kill. In these tests the pH ranged from 7.6 to 8.4 and the dissolved oxygen ranged from 6.9 to 9.1 p.p.m. All fish were 2 to 5 inches long.

TABLE 3.—*Toxicities of insecticides to rainbow trout and to caddicefly larvae in stream tests*

Formulation	Strength (p.p.m.)	Water temperature (°F.)	Rainbow trout			Percentage of caddicefly larvae killed in 24 hours	
			Number of tests	Percentage times no fish killed	Percentage fish killed in 24 hours	*Hydropsyche*	*Hesperophylax*
DDT							
Emulsion	0.03	67	1	100	0	0	0
	0.05	50–63	2	100	0	0	0
	0.10	42–55	2	100	0	0	0
	0.20	49–65	2	100	0	0	0
	0.30	42	1	0	10	0	0
	0.50	42–59	4	100	0	0	0
	0.70	46–65	5	100	0	0	0
	1.00	71	1	100	0	0	–
	5.00	63	1	100	0	0	–
	15.00	59	1	100	0	0	–
	15.00	66	1	0	60	–	–
Acetone solution	0.10	47–60	3	100	0	100	–
	0.20	47–70	2	100	0	100	–
	0.30	60–66	4	100	0	100	0
	0.30	47	1	0	10	100	–
	0.50	47	1	0	10	–	–
	0.50	60	1	100	0	100	–
Wettable	0.70	59–68	2	100	0	0	–
	1.00	61	2	100	0	0	–
	1.00	62	1	0	10	0	–
	1.50	60	1	0	20	0	–
	10.00	66	1	100	0	0	–
Fuel-oil solution	0.05	64	1	100	0	0	0
	0.10	64	1	100	0	0	–
	0.20	45–67	2	100	0	0	0
	0.40	46–66	4	0	10	0	–
	0.40	65	1	100	0	–	–
	10.00	66	1	100	0	0	–
Kerosene solution	0.30	62	1	100	0	0	–

TABLE 3.—(*Continued*)

Benzene hexachloride							
Emulsion	0.10	63	2	100	0	0	0
	0.50	47	1	0	10	–	–
	0.70	47	1	100	0	–	–
	1.00	47	1	100	0	–	–
Acetone solution	0.10	69	1	100	0	0	–
	0.30	47	1	0	10	–	–
	0.50	47	2	100	0	0	–
Chlorinated camphene							
Emulsion	0.20	64	1	100	0	0	0
	0.50	60	1	100	0	0	0
	1.00	64	2	100	0	0	0
	2.00	55	1	100	0	0	0
	3.00	56	1	0	60	0	0
	4.00	47–70	2	0	70	0	0
	5.00	67	1	100	0	0	–
Acetone solution	0.50	57	1	100	0	0	–
Fuel-oil solution	0.33	65	1	0	10	0	–
	0.50	58–66	2	100	0	0	–
Velsicol solution	0.50	60	2	100	0	0	–
	1.00	64	1	100	0	–	–
	2.00	64	1	100	0	–	–
Chlordan							
Emulsion	0.20	65	1	100	0	0	0
	0.50	60	1	100	0	0	0
	1.00	63	1	100	0	0	0
	2.00	45–61	3	100	0	0	0
	4.00	66	1	100	0	0	–
Acetone solution	0.10	61	1	100	0	0	–
	0.30	58	2	100	0	0	–
	4.30	61	1	0	20	0	–
	0.50	60	2	100	0	0	–
Fuel-oil solution	0.50	58–66	2	100	0	0	–
	6.00	63	1	100	0	–	–
Velsicol solution	0.50	63–65	3	100	0	–	–
	1.00	62–67	4	100	0	0	–
	15.00	66	1	100	0	–	–
	15.00	66	1	0	10	–	–

(*Continued on page 170*)

TABLE 3.—(*Continued*)—*Toxicities of insecticides to rainbow trout and to caddicefly larvae in stream tests*

Formulation	Strength (p.p.m.)	Water temperature (°F.)	Rainbow trout			Percentage of caddicefly larvae killed in 24 hours	
			Number of tests	Percentage times no fish killed	Percentage fish killed in 24 hours	*Hydropsyche*	*Hesperophylax*
Pyrethrins							
Acetone	0.10	59	1	100	0	–	–
Kerosene	0.10	63	1	100	0	90	80
Rutgers 612 repellent							
Commercial product	1.00	60–66	2	100	0	0	–
Dimethyl phthalate							
Solution	0.10	56	1	100	0	0	0
	0.70	60	1	100	0	0	0
Emulsion	1.00	65	1	100	0	0	0
Indalone							
Solution	2.00	63	1	100	0	0	0
Velsicol AR-50							
Solution	10.00	63	1	100	0	0	0
Fuel oil							
Commercial product	7.00	47	1	100	0	0	0
	9.00	68	1	100	0	0	0
	10.00	47	1	100	0	0	0
Kerosene							
Commercial product	20.00	67	1	100	0	0	0

emulsion. Six adult king salmon withstood 0.05 p.p.m. of DDT emulsion with no apparent effects.

Adult sticklebacks were somewhat more tolerant of some of the emulsions tested than were the salmonids, judging by the amount of agitation after 15-minute test periods. However, sticklebacks could not stand holding in the live cars, and mortalities were high at 24 hours. In stream tests of sticklebacks with pyrethrins in acetone at 0.1 p.p.m., it was noted that drastic effects resulted. The sticklebacks in live cars and those free in the stream were rendered helpless within the time of treatment, while only a few salmonids were so affected. Recovery was complete under these conditions, but it may be possible to utilize this toxicant in the control of sticklebacks without damaging salmonid fish in the same waters.

Toxicity of the Chemicals to Fish Food Organisms

Results of testing *Hydropsyche, Brachycentrus,* and *Hesperophylax* were not as consistent as those obtained from the experiments with fish. It was not possible to collect sufficient caddicefly material at the proper times to test all chemicals at all strengths, and not enough *Ephemerella* or stonefly material was available for adequate testing with these organisms.

Hydropsyche proved to be the least resistant of the caddiceflies. The pattern of toxicity of the poisons was essentially that shown in the tests with fish. Emulsions were more damaging than acetone suspensions, and benzene hexachloride was the chemical most toxic to caddice larvae. Tables 2 and 3 which list the results of trough and stream tests on caddiceflies show that 10 p.p.m. of acetone suspension of the four chief chemicals used is the lowest strength causing death, and that, except for benzene hexachloride, 5 p.p.m. of emulsions is the lowest strength killing these caddicefly larvae in 24 hours.

These data indicate that adequate margins of safety exist in relation to blackfly control in these streams, and, though the margins are not as wide as those relating to rainbow trout, it is possible to effect blackfly control without directly harming this segment of the food of the fish.

The Place of Blackfly Larvae in the Diet of Salmonids

It is important to know whether the removal of simuliid larvae from a stream will deprive the fish of an important portion of the food that would be gleaned from the stream bottom. The place of these larvae in the diet of trout and salmon varies from stream to stream and depends upon the abundance and availability of the insects, as well as the amount of other food at hand.

A small number of fish stomachs were examined in connection with this study, with the object of determining the percentage of total food represented by simuliid larvae. Only fish from streams with heavy infestations of blackflies were examined so that there would be no question as to abundance. Table 4 summarizes the results of the stomach analyses.

The average percentage of total food by weight represented by blackfly

TABLE 4.—*Food content of salmonid stomachs*

Stream	Date (1947)	Number of fish	Species	Average length (millimeters)	Average number of blackflies per stomach	Percentage of food by weight
Campbell Creek..	June 5	4	Dolly Varden	116	1	1
Valdez Creek....	June 26	12	Dolly Varden	146	14	4
Otter Creek.....	June 26	16	King salmon	94	3.5	1
Otter Creek.....	June 26	3	Rainbow trout	159	4	3
Willow Creek....	July 11	10	Dolly Varden	190	0	0
Otter Creek.....	Aug. 20	11	Red salmon	60	0.2	1
Campbell Creek..	July 30	7	Rainbow trout	75	1.5	3

larvae was 1.8 and the average number of larvae per stomach was 4.0.

Chapman and Quistorff (1938) showed that in streams of the Columbia River drainage steelhead trout and king salmon ate blackfly larvae only in limited quantities. Of 819 steelhead trout stomachs examined, 1,397 larvae were found in 66 stomachs, or 1.7 larvae per stomach. (The mean was 21.1 larvae per stomach, in the 66 in which larvae were found.) In 309 king salmon stomachs, 42 larvae were found in 9 stomachs, or 0.13 larvae per stomach. (The figure was 4.6 larvae per stomach, of the 9 in which larvae were found.)

Allen (1941), in his study of the feeding habits of *Salmo salar* in the River Eden in northern England and in the River Thurso in northern Scotland, showed that first-year and second-year salmon in those streams ingested blackfly larvae in different amounts. First-year fish in the Thurso system had simuliid larvae as 7.4 percent by weight of the total food. In the Eden system, the corresponding amount was 2.0 percent. For the second-year fish, 7.9 percent of the food in the Thurso was blackfly larvae, while 21.3 percent was represented in the Eden.

Leonard (1942) found that on January 18, 1941, *Simulium venustum* larvae constituted 53.2 percent of the total volume of food in the stomachs of 22 brook trout (*Salvelinus fontinalis*). The average number of individual blackflies per stomach was 155. On January 24, 1941, stream-bottom samples of the section from which the fish were taken revealed that *Simulium* represented 16.2 percent by volume of the bottom fauna. It is doubtful that these organisms would play such an important role as fish food during summer and autumn months.

Idyll (1942) has shown the results of stomach analyses for series of rainbow, cutthroat, and brown trout in the Cowichan River system on Vancouver Island in British Columbia. The fish were collected mostly in the period from May to September and a wide assortment of size groups below 56 centimeters was represented for each species. It was found that in 220 rainbow trout stomachs, the average number of blackfly larvae per stomach was 93.1. The cutthroat trout taken from the river had an average of 6.1 blackfly larvae per stomach in 120 stomachs, with none present

in 27 percent of the stomachs. Brown trout averaged 6.1 blackfly larvae per stomach in 110 stomachs, with none present in 34 percent of the stomachs. In Idyll's study, simuliids appeared to be of little importance to fish less than 30 centimeters long, but in two size groups above 30 centimeters, over 60 percent by number of the food animals were blackfly larvae.

These studies suggest that simuliids are sometimes of importance in the diet of trout and salmon. The numbers of blackfly larvae consumed vary with species and size of fish, time of year, and locality. The present study, however, shows that blackfly larvae do not constitute a substantial proportion of the food of trout and salmon in the vicinity of Anchorage, Alaska, and that deprivation of this item through chemical control need not be considered as seriously detrimental.

The suggestion that fish may receive high concentrations of toxicants through the ingestion of blackfly larvae which have been dislodged from their anchorages by the toxicants has been considered. The question has been answered in part by the work of Surber (1947a), who fed treated houseflies to bluegill sunfish of 82 millimeters average length. The flies had previously been sprayed with DDT in oil at the rate of 1.0 pound per acre. No bluegills were killed in this experiment, corroborating a 1945 test which failed to show that this fish can be killed by feeding upon insects sprayed with DDT. A personal communication from C. H. Hoffmann says, "Other experiments by Surber and Hoffman have shown that several fresh-water fish, including bluegills, can be killed by feeding upon insects, particularly fly larvae, treated at the rate of 1 pound of DDT per acre. Some fish apparently were killed by devouring relatively small numbers of sprayed insects; others gorged themselves without effect. Larger fish were less sensitive than small fish, and those devouring oil-sprayed insects were ordinarily killed sooner than those devouring insects sprayed with a DDT suspension." No such tests with blackflies and trout are known to the authors. It was noted during stream tests in Alaska that fish were reluctant to eat during the course of treatment, but undoubtedly some feeding does take place during the several hours after treatment when the detached larvae are being washed downstream. Hoffman, in a personal communication, writes, "Our experience in the United States indicates that within a few minutes after streams are sprayed with a 1-pound-per-acre dosage of DDT in oil, many aquatic insects become affected, and the number of rises made by several species of trout over a given period of time far exceeds those made before the spraying."

Practical Control

A summary of the significant features of the figures accumulated in the study is presented in Table 5, in which are listed the limits for the two most essential items of data necessary for practical control through the use of any of the chemical agents tested. The margin of safety for any of the various toxicants is the difference between the minimum disabling strength

TABLE 5.—*Summary of minimum disabling dosages of insecticides for rainbow trout fingerlings and caddicefly larvae and minimum effective dosages against blackfly larvae*[1]

Toxicant	Formulation	Minimum disabling or lethal concentration (p.p.m.)		Minimum concentration (p.p.m.) for blackflies
		For rainbow trout	For caddicefly larvae	
DDT	Emulsion	8.0	8.0	0.7
	Acetone solution	35.0	15.0	0.3
	Wettable	[2]10.0	[2]10.0	1.0
	Fuel-oil solution	[2]10.0	[2]10.0	0.4
	Kerosene solution	[2]0.3	[2]0.3	0.3
Benzene hexachloride	Emulsion	1.0	1.0	1.0
	Acetone solution	10.0	15.0	[3]0.5
Chlorinated camphene	Emulsion	3.0	8.0	4.0
	Acetone solution	8.0	10.0	[3]0.5
	Fuel-oil solution	[2]0.5	[2]0.5	[3]0.5
	Velsicol solution	[2]2.0	[3]0.5	[3]1.5
Chlordan	Emulsion	5.0	5.0	4.0
	Acetone solution	30.0	15.0	[3]0.5
	Fuel-oil solution	[2]6.0	[2]0.5	0.5
	Velsicol solution	15.0	[2]1.0	[3]1.5
Pyrethrins	Acetone mixture	0.1	–	[3]0.1
	Kerosene solution	[2]0.1	0.1	[3]0.1

[1] In deriving these figures from Tables 2 and 3, isolated mortalities have been disregarded when subsequent tests at higher concentrations did not cause damage to the organisms tested
[2] No disablement at this strength which was the highest concentration tested
[3] Ineffective at this strength which was the highest concentration tested

in relation to trout and to caddicefly larvae and the minimum amount necessary for blackfly control.

The various criteria for the choice of an insecticide for a particular control task should be carefully considered when planning is being done. Aside from considerations such as availability of toxicant and solvents, cost of materials, and ease and safety of handling the formulation, a chemical of choice would be one with a wide margin of safety based not on minimum killing strength but on minimum disabling concentration.

Safe control is dependent upon the careful dispensing of the correct amount of chemical at a steady rate. The calculation of the proper strength and volume of toxicant calls for an accurate measurement of stream flow. Of the methods used for such a measurement in the present study, the notched weir was selected as offering the most dependable and practical means. Consideration must always be given to contributions to the flow in the section of stream being treated, and allowance must be made for tributaries and springs which would dilute the toxicant used for control.

Another technique in good control is the provision for rapid dispersal of the chemical at a point near the place of application. This aim may be accomplished by applying the fluid at a turbulent place in the stream, by the use of multiple outlets from the chemical tank, or by the utilization of a deflector in the path of the falling liquid.

The time of occurrence of fish populations in a stream should be investigated in relation to the time of presence of blackfly larvae. The dates of upstream movement of spawners and the downstream movement of seaward migrants should be known before treatment is made in order that the chances for damage to fish life may be minimized. When these facts are known and it has been decided how many treatments per season must be made for effective blackfly control, the exact dates of treatment should be set so as to coincide with the presence of a minimum number of fish in the stream. In some places it may be possible to treat a stream before the spring migrations of anadromous fish are under way, aand thus reduce the hazards to fish. In other places control operations may be carried on between spring and fall runs and at a time when fry and fingerlings are not moving in great numbers.

Summary and Conclusions

In a study conducted in central Alaska in 1947, tests were made of the effects of some new insecticides on native freshwater fishes in relation to blackfly control operations. The principal chemicals tested were DDT, benzene hexachloride, chlorinated camphene, and chlordan; the fishes tested were rainbow trout, Dolly Varden trout, red salmon, silver salmon, king salmon, and stickleback. Several formulations of each toxicant were tested, and both fingerling and adult salmonids were used in the work.

Fish, fish-food organisms, and blackfly larvae were tested simultaneously in both hatchery-trough experiments and under actual stream conditions.

Although all four toxicants tested were found to cause mortality to trout and salmon, it took considerably more of some substances to damage fish than it did to cause blackfly larvae to detach from rocks on the stream bottom and be carried downstream by the current. Of the four chief toxicants used, DDT was the least harmful to the fish, benzene hexachloride the most drastic; chlorinated camphene and chlordan were similar and occupied an intermediate position. Xylene-Triton emulsions showed the strongest effects of all formulations used and acetone suspensions were the least toxic. The fuel-oil solutions, Velsicol AR-50 solutions, and kerosene solutions exhibited effects between the first two formulations mentioned. Chlorinated camphene in acetone suspension showed a delayed mortality on fish, a trait not indicated for the other toxicants used.

The pattern of effectiveness against the fish was repeated by the insecticides against caddicefly larvae of the genera *Hydropsyche, Hesperophylax,* and *Brachycentrus,* except that in general the tolerance of the caddiceflies was slightly greater than that of the fish.

The following insecticides were the most promising for safe effective control:

1. DDT in acetone suspension, at least 0.3 p.p.m. but less than 15 p.p.m. below 70° F., at the rate of 1 gram of chemical to 100 cubic centimeters of acetone.

2. Chlordan in acetone suspension, more than 0.5 p.p.m. but less than

15 p.p.m. below 70° F., at the rate of 1 gram of chemical to 100 cubic centimeters of acetone.

3. DDT in fuel-oil solution, at least 0.4 p.p.m. but less than 10 p.p.m. below 70° F., the solution to be 5-percent chemical.

4. Chlordan in fuel-oil solution, at least 0.5 p.p.m. but less than 6 p.p.m. below 70° F., the solution to be 5-percent chemical.

5. Toxaphene in acetone suspension, more than 0.5 p.p.m. but less than 8 p.p.m. below 70° F., the chemical to be at the rate of 1 gram to 100 cubic centimeters of acetone.

For the fuel-oil solutions the 5-percent solution need not be the only practical strength to give good results. If a smaller volume of a higher strength of fuel-oil solution is preferred, it seems likely that equivalent results may be had.

A stomach-content analysis showed that salmon and trout in the test area ingested only limited numbers of blackfly larvae. The larvae represented an average of 1.8 percent by weight of the total stomach contents, and their loss as fish food through a control program in this area is not here considered as serious.

In the light of recent work by Surber and Hoffman in the United States, it might be expected that some damage to fish could result from their ingestion of treated blackfly larvae detached from rocks.

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AGE AND GROWTH OF THE LAKE WHITEFISH, *COREGONUS CLUPEAFORMIS* (MITCHILL), IN LAKE ERIE

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ABSTRACT

Although the whitefish has by no means ranked first from the standpoint of production, it has always been an important commercial species in Lake Erie. Trends in the output of whitefish have differed in the United States and Canadian waters of the lake. The 1893–1946 average annual yield of 1,201,000 pounds in the United States was only 38.3 percent of the 1879–1890 mean of 3,133,000 pounds, whereas in Canada the more recent (1907–1946) average annual take of 1,397,000 pounds has been 5.48 times the 1871–1906 mean of 255,000 pounds. The United States fishery was centered in the western part of Lake Erie (61.5 percent of the production in Michigan and Ohio) before 1921 and in the eastern part (62.6 percent in Pennsylvania and New York) in 1921–1946. The eastern part of Lake Erie (east of Port Burwell) dominated the Canadian production in 1900–1909 (65.4 percent) and in 1922–1946 (57.2 percent) but the western end was the more productive in 1871–1899 (79.8 percent) and 1910–1921 (69.7 percent).

Ages were determined and individual growth histories calculated from the examination and measurement of the scales of 3,399 Lake Erie whitefish captured off four ports (Sandusky, Lorain, and Conneaut, Ohio, and Erie, Pennsylvania)

over the period, 1927–1930. The number of specimens used for the investigation of other phases of the life history varied according to the amount of data available or required.

Age-group III was typically (but not invariably) dominant in random samples from gear employed for the commercial production of whitefish (trap nets, pound nets, and large-mesh gill nets). The same age group also dominated most samples of the marketable catch (that is, whitefish that equalled or exceeded the minimum legal weight of 1¾ pounds) taken in late summer, autumn, and early winter. Age-group IV, however, was strongest among marketable fish from trap nets in early July although the III group was dominant in the random samples from the same nets. Apparently the members of a year class normally dominate the commercial catch about one year but this year extends over parts of two years of life (latter part of the fourth and early part of the fifth). The oldest whitefish in the collections were in the seventeenth year (age-group XVI).

The year classes of 1922 and 1926 were much stronger than average whereas the 1923 year class seems to have been exceptionally weak. No correlation was detected between limnological-meteorological conditions and the strength of the year classes.

Whitefish collected off different ports exhibited differences of growth rate that were at times rather large. The distorting effects of such factors as selection on the basis of maturity, annual fluctuations in growth rate (in combination with differences in the year of capture), and gear selection were held to be sufficiently great, however, to render doubtful the real biological significance of the observed variations in growth. Consequently the data for all samples were combined to obtain general growth curves.

Female whitefish averaged longer and heavier than male fish of corresponding age. The advantage of the females with respect to calculated lengths tended to increase during the first three years of life and thereafter remained nearly constant at about one-half inch total length (10 millimeters of standard length). The advantages of the females with respect to weight increased consistently from 0.01 pound at the end of the first year to 0.36 pound at the end of the eighth, dropped to 0.32 pound in the ninth year, and increased again to a maximum of 0.47 pound at the end of 12 years.

The maximum growth in length (sexes combined) occurred in the first year of life (calculated growth of 6.9 inches, total length). From this value the calculated annual increments declined rapidly to 0.7 inch in the seventh year. The later increments varied irregularly, ranging from 0.7 inch in the eighth and ninth years down to only 0.3 inch in the fifteenth and sixteenth years. The Lake Erie whitefish was a foot long in a little less than 2 years, 18 inches in about 4 years, and 2 feet in slightly under 12 years. At the end of 16 years the calculated length was 25.6 inches.

The calculated annual increments of growth in weight increased from 0.10 pound in the first year to a maximum of 0.76 pound in the third. In the succeeding years the increment decreased consistently to 0.33 pound in the twelfth year. The values in the thirteenth to sixteenth years varied irregularly, ranging from 0.22 to 0.34 pound. The minimum legal weight of 1¾ pounds was attained toward the middle of the fourth growing season. The Lake Erie whitefish reached the weight of 4 pounds in between 7 and 8 years, and of 6 pounds in about 13 years. At the end of 16 years the calculated weight was 6.87 pounds.

Analyses of the annual increments of length revealed that the growth of whitefish captured from the spawning run off Sandusky and Lorain rose from 3.2 percent above the 1924–1930 mean in 1924 to a peak of 15.0 percent above average in 1927 and then declined to a minimum of 25.0 percent below average in 1930. There is evidence that these annual fluctuations in growth rate were correlated negatively with fluctuations in the turbidity of the water off Erie,

Pennsylvania (to our best knowledge the whitefish spends the summer months in the eastern part of the lake), in certain months (especially May and June) and/or correlated positively with the amount of rainfall in July and August at the same locality.

Comparisons with data on the growth of the Lake Huron whitefish revealed that Lake Erie fish were the longer during the first 5 years of life and the shorter at the end of the sixth and later years. The Lake Huron whitefish did not, however, gain the advantage in weight until the seventh year. Whitefish grew much more slowly in both length and weight in Lake Ontario than in either Lake Huron or Lake Erie.

The weight of the Lake Erie whitefish increased to the 3.1523 power of the length. Agreement between empirical weights and those computed from the length-weight equation was reasonably good at lengths represented by fair numbers of fish. The total length corresponding to the minimum legal weight of 1¾ pounds was calculated as 16.9 inches.

The rather limited data on the monthly fluctuations in condition indicated that the coefficient *K* of immature fish declined continuously from August to December. A similar though less pronounced decline of *K* of mature fish occurred from August to October. At spawning in November and December, female whitefish lost an additional 11 percent of their body weight. No loss of weight at spawning could be demonstrated for the males.

The available records indicated the relative abundance of the sexes to be approximately equal in samples collected in the summer and early autumn. Males were strongly predominant (78.6 percent), however, in spawning-run samples. In these collections the percentage of males decreased markedly with increase in age. No trend could be detected in the variation of the sex ratio within the spawning season over the period of time (nearly 4 weeks) for which there were records.

Although exceptional individuals of either sex may mature at the end of 2 years of life (age-group I) male whitefish do not mature in appreciable numbers until the end of the third year (age-group II) or females until the end of the fourth (age-group III). Apparently most or all males are mature as age-group III, but there is evidence that considerable numbers of females (possibly a majority) are first mature as members of the IV group (end of fifth year of life). Whether Lake Erie whitefish are ever immature as the V group or older is not known.

Spawning commenced during the second week of November and was continuing actively at the time of collection of the last samples at the end of the first week of December.

Introduction

The present study of the age and growth of the whitefish is another in a series of papers on the life histories of Lake Erie fishes based on materials collected during the course of a cooperative investigation [1] of the limnology and fisheries of the lake. Previous publications have included preliminary reports on the growth of the pikeperches, *Stizostedion* spp., (Deason, 1933) and of the yellow perch, *Perca flavescens,* (Jobes, 1933) and studies of the growth of the sheepshead or freshwater drum, *Aplodinotus grunniens,*

[1] The States of New York, Pennsylvania, and Ohio, and the United States Bureau of Fisheries (now incorporated in the Fish and Wildlife Service) participated in the investigations.

(Van Oosten, 1938) and of the white bass, *Lepibema chrysops,* (Van Oosten, 1942). Detailed investigations by Deason on the growth and morphometry of the pikeperches and by Jobes on the growth of the yellow perch have been completed and are now in manuscript form.

Although the whitefish has by no means ranked first from the standpoint of production, it has always been of significance in Lake Erie. The great popularity of the whitefish and the excellent price that it ordinarily brings have given the species an importance out of proportion to the mere production in pounds.

Materials and Methods

The 3,399 Lake Erie whitefish for which ages were determined and growth histories calculated from the examination and measurement of scales were captured off four ports by various types of gear from 1927 to 1930 (Table 1; see Fig. 1 for localities). The Sandusky collection con-

Table 1.—*Date, locality, and gear of capture of Lake Erie whitefish employed for the study of age and growth*

Year	Port	Date	Gear				Total
			Trap net	Pound net	Small-mesh gill net	Large-mesh gill net	
1927	Sandusky, O.	Sept. 24	.....	...	...	1	1
		Oct. 12–31	3	...	...	.....	3
		Nov. 9–29	100	...	...	446	546
1928	Sandusky, O.	Oct. 26	89	...	...	.....	89
		Nov. 2–20	50	...	...	.....	50
		Dec. 4	129	...	...	.....	129
	Erie, Pa.	Sept. 1–29	.....	...	[1]69	117	186
		Oct. 5–19	.....	[2]2	12	.....	14
		Nov. 2–30	.....	...	99	.....	99
		Dec. 1–10	.....	...	67	.....	67
1929	Sandusky, O.	Nov. 5–27	647	...	...	236	883
	Lorain, O.	Aug. 12	1	...	...	.....	1
		Nov. 20–26	148	...	...	.....	148
		Dec. 4–7	74	...	...	.....	74
	Conneaut, O.	July 9–12	189	...	...	.....	189
	Erie, Pa.	July 22–29	.....	...	14	.....	14
		Aug. 2–29	.....	...	72	71	143
		Sept. 4–29	.....	...	85	119	204
		Oct. 3–22	.....	252	...	21	273
1930	Lorain, O.	Nov. 5–23	286	...	...	.....	286
1927–1929	Sandusky, O.	All months	1,018	...	...	683	1,701
1929–1930	Lorain, O.	do.	509	...	...	.....	509
1929	Conneaut, O.	do.	189	...	...	.....	189
1928–1929	Erie, Pa.	do.	.....	254	418	328	1,000
1927	All ports	All months	103	...	...	447	550
1928	do.	do.	268	2	247	117	634
1929	do.	do.	1,059	252	171	447	1,929
1930	do.	do.	286	...	...	.....	286
Total	All ports	All months	1,716	254	418	1,011	3,399

[1] Includes 2 large fish selected for size
[2] Both large fish selected for size

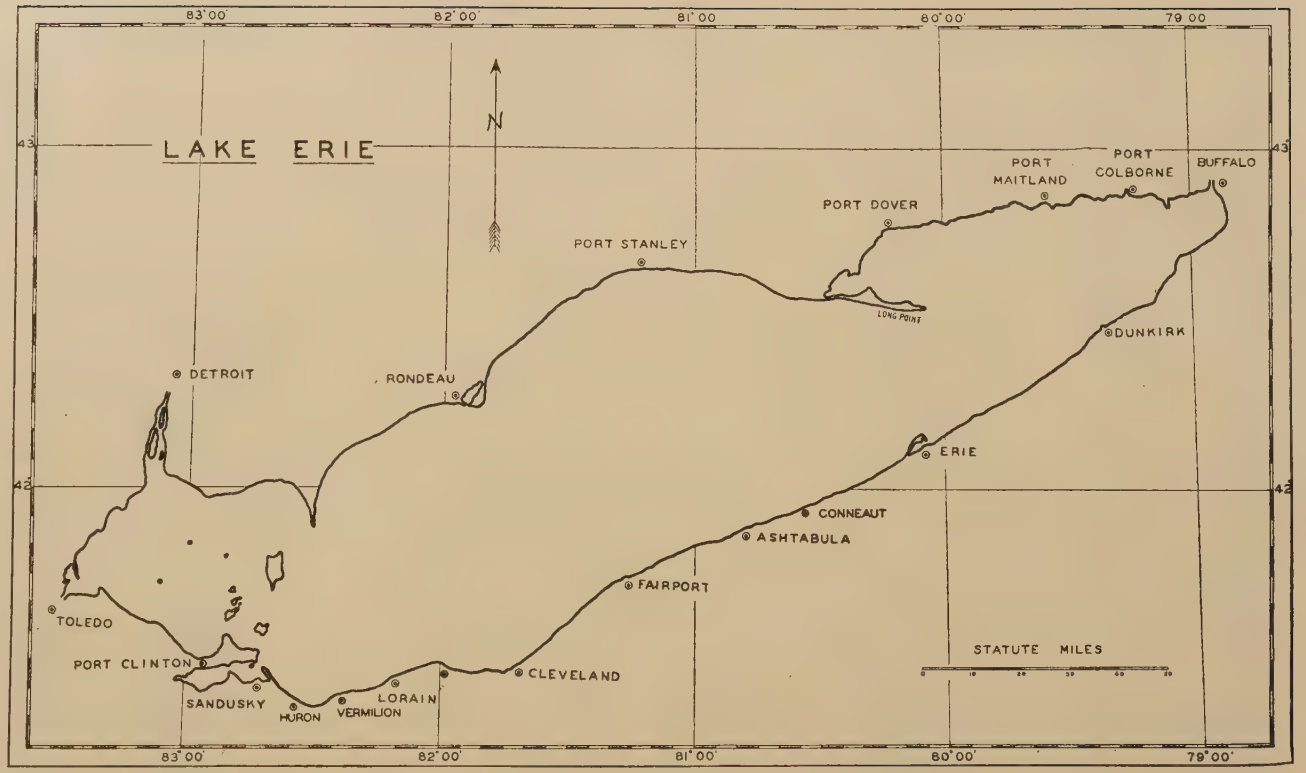

FIGURE 1.—Map of Lake Erie showing principal ports.

tained the greatest number of fish from any port—1,701 or 50.0 percent of the combined collections. The numbers for the remaining ports were: Lorain—509; Conneaut—189; Erie—1,000.

More than half of the whitefish (1,716 or 50.5 percent) were captured in trap nets. The remainder were taken in pound nets (254), small-mesh gill nets [2] (418), and large-mesh gill nets (1,011). Most of the trap-net collections came from commercial gear with 2- to 2⅞-inch meshes (extension measure as manufactured) in the cribs or pots, although a few samples from Lorain were taken by experimental trap nets with slightly larger meshes (3 inches). No differences were found in the size of whitefish captured in the two types of trap net. The pound-net samples were from nets with 2 11/16-inch meshes in the lifting pot. The mesh sizes of the small-mesh and large-mesh gill nets were approximately 3 and 4¾ inches, respectively. Small-mesh gill nets were not fished commercially for whitefish; large numbers of undersized individuals were taken, however, when these nets were set for ciscoes, and it was generally known that at certain times and localities immature whitefish made up a considerable percentage of the fish marketed as ciscoes. The 4¾-inch-mesh gill net is a standard commercial gear for the capture of whitefish on Lake Erie.

By no means were all of the whitefish for which ages were determined employed in the study of growth since the samples of certain age groups had to be excluded as certainly or most probably unrepresentative. These age groups are listed below for the different collections.

Sandusky and Lorain—trap-net collections.—Age-groups I and II [3] were excluded (no 0-group fish occurred in any of the Lake Erie collections) because of probable selection on the basis of maturity. The collections from these two ports were made almost exclusively during the spawning period. Since spawning-run samples tend to contain only mature fish, and since relatively few whitefish, especially females, seem to reach maturity before the fourth year, age-groups I and II probably were represented only by the larger, mature individuals.

Sandusky—large-mesh gill-net collections.—Age-groups I to IV, inclusive, were excluded. Comparisons of the average lengths of age groups in trap-net and gill-net samples demonstrated that large-mesh gill nets tended to select the larger individuals of all groups younger than age-group V. These comparisons provided valid estimates of the selective action of gill nets with respect to the size of the fish since impounding nets are selective only for the smaller fish, and the meshes of the trap nets were sufficiently small to retain whitefish of the II group and older individuals and probably all I-group fish. (The I-group whitefish of the Lorain and Sandusky collections had completed two years of growth and hence were not subject to the selection that is believed to have affected the samples of age-group I taken off Conneaut early in the second year—see next paragraph.)

Conneaut—trap-net collection.—Age-group I was excluded. It was considered probable that the smaller individuals of this age group (early in their second year of growth at the time of the collection of the samples) may have escaped through the

[2] These nets included both deep or "bull" nets and shallow or "shoal" nets. No diffrences were found in the samples of whitefish from the two gears.

[3] Ages are designated in this paper by Roman numerals corresponding to the number of annuli or year-marks. Most of the whitefish in the collections, however, were captured in late summer, autumn, or early winter, and therefore had completed nearly, if not fully, one more season of growth than indicated by the number of annuli.

TABLE 2.—*Relationship between gear of capture and the average total length (inches) of the members of the best represented age groups in the collections from Erie, Pennsylvania, 1928 and 1929*

[Numbers of fish in parentheses]

Gear	Age group		
	II	III	IV
Small-mesh gill nets	14.4 (167)	16.7 (60)	18.6 (14)
Pound nets	16.2 (5)	17.8 (172)	19.0 (59)
Large-mesh gill nets	16.3 (10)	18.0 (221)	19.1 (85)
All gears	14.5 (182)	17.7 (453)	19.0 (158)

meshes of the trap nets. There was no reason to believe that selection according to maturity affected these July samples; consequently the data for age-group II were retained in the study of growth.

Erie—collections of all gears.—No age groups were excluded. Since no collections were made during the spawning run,[4] selection according to maturity probably did not affect the samples greatly. Rather large differences were found between the average lengths of whitefish of the same age but captured by different gears (Table 2). However, the selection according to gear was to some extent compensatory. For example, large-mesh gill nets appeared to take the larger and small-mesh gill nets the smaller individuals of the age groups represented in the collections for both gears. (Whitefish from pound nets averaged slightly smaller than those from large-mesh gill nets.) Because of this compensatory effect in the gill-net samples, and because of the scarcity of specimens from the less selective pound nets the data based on the combination of all materials were considered to provide the most reliable estimate of growth available.

It is not intended to imply that the elimination of the data for certain age groups in the computation of growth curves has made the collections homogeneous and representative samples of the "natural" populations of whitefish. The problem of adequate sampling is not disposed of so easily, especially when the samples must be taken by commercial gear and from a stock subjected to an intensive fishery—a fishery in which individuals are destroyed selectively on the basis of such factors as rate of growth and size at first maturity. Although the exclusion of certain age groups has increased greatly the reliability of the data on growth, extremely troublesome problems of selection remain nevertheless. For example, the selection according to maturity which formed the basis for the exclusion of the data for age-groups I and II of the spawning-run samples doubtless exerted some effect on the averages for age-group III and may even have affected slightly the data for age-group IV.

It is true also that the combination of the samples from all gears in the Erie collections provided apparently the best estimate of growth to be had

[4] The whitefish collected off Erie in November and December, 1928, were young immature fish captured by small-mesh gill nets at a distance from the spawning grounds.

from the materials at hand, but did not guarantee that the averages obtained were entirely free from the distorting effects of gear selection.

Factors of selection must be considered also in the interpretation of the data on other phases of the life history of the Lake Erie whitefish—the relative abundance of the age groups and year classes, length-frequency distributions, sex ratios. . . . In the later sections we shall have occasion to mention repeatedly the various effects of selection. Problems on the interpretation of the observed differences in the growth of whitefish from different localities will be treated in some detail on pp. 208–210.

These defects in the materials have been described briefly in order to bring out the necessity of certain reservations in the interpretation of data to be presented in later sections. Although the defects impose limits on the interpretation of the data they do not affect their general reliability. Indeed, certain agreements (as the close correspondence between the sexes and between the Sandusky and Lorain collections with respect to annual fluctuations in growth rate—p. 223) suggest that for some phases of the life history of the whitefish the data may be reliable within rather narrow limits.

The numbers of individuals employed in the study of the different phases of the life history of the Lake Erie whitefish varied according to the nature of the data available for the different samples or required in a particular situation. These numbers need not be listed here; they will be given in the various sections to follow.

The technical procedure, which was that commonly employed in similar studies of age and growth, will be outlined only briefly.

Standard lengths (to the base of the caudal fin) were measured for all individuals and total lengths (to the tip of the tail with the lobes compressed to give the maximum possible measurement) were obtained for a sufficient number to determine conversion factors between the two measurements. All measurements were made by means of a steel tape [5] and were recorded to the nearest millimeter. Lengths given in this paper are total if stated in inches and standard if stated in millimeters. Weights were determined by means of a spring balance and were recorded to the nearest quarter-ounce. Scales were mounted on a glass slide and examined and measured by means of a microprojection apparatus.

The validity of age determinations from whitefish scales was established by Van Oosten (1923) who demonstrated also that direct-proportion calculations of growth based on diameter measurements of the scale are satisfactorily accurate.

Ages were determined for slightly more than 98 percent of the whitefish from which scales were examined. (Fish that were represented by regenerated scales only were excluded in the computation of this percentage.) This relatively high percentage may be ascribed to the abun-

[5] The lengths of whitefish of the 1930 collection from Lorain were read from a measuring board but later were converted to "tape lengths" by means of an empirically determined factor. Tape lengths were 1 percent greater than board lengths.

dance of young fish in the samples and to the relatively clear markings on the scales of most Lake Erie whitefish.

Production of Whitefish in Lake Erie

The earliest available record of whitefish production in the United States waters of Lake Erie is for 1879 (repeatedly listed erroneously in published statistics as for 1880). The data for subsequent years are scattered up to 1913. Beginning with this year there are continuous statistics of yield for all United States waters combined and also for the individual states with the exception of 1925 (data lacking for Pennsylvania and New York in that year). The statistics in Table 3 for United States waters for the period 1879–1940 were taken from the report of the International Board of Inquiry for the Great Lakes Fisheries (Gallagher and Van Oosten, 1943). Those for later years were compiled in the Great Lakes laboratory of the Fish and Wildlife Service at Ann Arbor, Michigan, or supplied by the States of Ohio, Pennsylvania, and New York.

Canadian (Province of Ontario) records of catch begin with 1867. However, the recorded yields for 1867–1870 included whitefish taken in the Detroit River and in Lake St. Clair as far north as the mouth of the Thames River. Consequently the figures for these four early years were omitted from Table 3 and were not graphed in Figure 2. The statistics of whitefish production in the Canadian waters of Lake Erie through 1939 are from Ford (1943). Data for later years were supplied by the Ontario Department of Lands and Forests.

The catch of whitefish in the United States waters of Lake Erie exceeded 3 million pounds in each of the first three years for which records are available (1879, 1885, and 1889) and was well above 2 million pounds in the fourth year (1890). The 1885 production of 3,532,000 pounds was the largest for which we have a record. The average yield in this early period, 1879–1890, was 3,133,000 pounds.

In the later years, 1893-1946, the catch of whitefish fluctuated widely, but was generally at a much lower level. The 1893–1946 average production of 1,201,000 pounds was only 38.3 percent of the 1879–1890 mean. During the 39 years for which there are records from 1893 to 1946 the yield of whitefish dropped below 500,000 pounds 3 times, was between 500,000 and a million pounds in 17 years, varied between 1 and 2 million pounds in 14 years, and exceeded 2 million pounds in 5 years. The lowest catch of the period occurred in 1924 (331,000 pounds) and the highest in 1940 (2,643,000 pounds). The production of the latter year was the greatest recorded since 1889.

Rather pronounced changes have taken place in the distribution of the yield of whitefish among the different states. Prior to 1921 the Ohio catch dominated the United States production in 13 of 15 years (exceptions in 1885 and 1913—incomplete data for Ohio and defective information for Pennsylvania in the latter year) and made up 52.3 percent of the average annual production for the period 1885–1920 (Tables 3 and 4). The west-

TABLE 3.—*Production (thousands of pounds) of whitefish in Lake Erie, 1871–1946*

Year	United States					Canada			Entire lake
	Michigan	Ohio	Pennsylvania	New York	Total	Western portion[1]	Eastern portion[2]	Total	
1871	...	.....	.....	...	.....	30	36	65	.....
1872	...	.....	.....	...	.....	136	48	185	.....
1873	...	.....	.....	...	.....	178	70	248	.....
1874	...	.....	.....	...	.....	94	17	111	.....
1875	...	.....	.....	...	.....	88	38	126	.....
1876	...	.....	.....	...	.....	50	49	99	.....
1877	...	.....	.....	...	.....	94	46	141	.....
1878	...	.....	.....	...	.....	167	15	183	.....
1879	...	.....	.....	...	3,334	186	16	203	3,537
1880	...	.....	.....	...	.....	187	19	206	.....
1881	...	.....	.....	...	.....	269	43	312	.....
1882	...	.....	.....	...	.....	262	21	284	.....
1883	...	.....	.....	...	.....	197	25	222	.....
1884	...	.....	.....	...	.....	199	31	230	.....
1885	133	1,249	2,120	30	3,532	164	22	186	3,718
1886	...	.....	.....	...	.....	128	13	142	.....
1887	...	.....	.....	...	.....	288	46	333	.....
1888	...	.....	.....	...	.....	321	69	390	.....
1889	50	1,743	1,160	371	3,324	238	68	306	3,630
1890	136	1,130	758	318	2,341	181	23	204	2,546
1891	144	.....	.....	...	.....	304	46	350	.....
1892	143	.....	.....	...	.....	242	70	312	.....
1893	61	.....	.....	...	1,292	208	49	256	1,549
1894	75	.....	.....	...	.....	130	23	153	.....
1895	104	.....	.....	...	.....	126	22	148	.....
1896	59	.....	.....	...	.....	106	20	126	.....
[3]1897	147	400	169	58	774	182	88	270	1,044
1898	108	.....	.....	...	.....	165	81	245	.....
1899	315	1,050	616	172	2,153	238	194	431	2,584
1900	251	.....	.....	...	.....	194	208	401	.....
1901	282	.....	.....	...	.....	258	268	526	.....
1902	226	.....	.....	...	.....	196	253	450	.....
1903	57	172	53	52	335	128	176	303	638
1904	96	.....	.....	...	.....	193	170	364	.....
1905	133	.....	.....	...	.....	142	162	304	.....
1906	187	.....	.....	...	.....	124	235	359	.....
1907	230	.....	.....	...	.....	308	326	634	.....
1908	236	732	455	123	1,546	348	478	826	2,372
1909	...	.....	.....	...	.....	446	2,151	2,597	.....
1910	...	.....	.....	...	.....	745	638	1,384	.....
1911	...	.....	.....	...	.....	804	336	1,139	.....
1912	341	.....	.....	...	.....	2,159	422	2,580	.....
1913	411	[4]246	[5]836	16	1,510	1,578	402	1,980	3,489
1914	274	1,205	596	[5]58	2,133	1,395	598	1,993	4,126
1915	33	653	359	100	1,145	1,377	455	1,832	2,978
1916	107	683	18	123	930	680	406	1,086	2,016
1917	187	1,404	22	164	1,777	846	394	1,240	3,016
1918	227	1,028	187	159	1,600	716	412	1,128	2,729
1919	69	1,084	464	94	1,711	749	346	1,094	2,805
1920	36	934	367	89	1,426	455	383	838	2,264
1921	14	321	490	98	922	523	443	966	1,889
1922	12	209	362	[5]205	787	370	382	752	1,539
1923	[6]...	188	67	[5]234	489	.....	.....	536	1,025
1924	1	[7]148	112	71	331	199	382	580	911
1925	[6]...	300	.....	...	583	359	674	1,033	1,616
1926	[6]...	245	605	110	961	312	556	868	1,829
1927	[6]...	242	288	94	624	346	402	748	1,372
1928	1	415	402	156	974	415	573	988	1,962
1929	[6]...	535	317	227	1,079	431	836	1,268	2,347
1930	1	597	755	169	1,522	293	795	1,088	2,609
1931	3	572	644	54	1,273	505	601	1,106	2,379
1932	19	507	447	195	1,169	419	493	912	2,081
1933	4	197	664	132	997	329	381	710	1,707
1934	2	279	463	35	779	596	320	916	1,694
1935	2	477	487	29	995	605	585	1,190	2,185
1936	1	330	804	23	1,158	439	1,328	1,768	2,926
1937	1	123	429	94	647	365	1,036	1,401	2,048
1938	2	292	526	91	911	400	601	1,002	1,913
1939	1	994	980	123	2,098	1,718	594	2,312	4,410
1940	2	643	1,564	433	2,643	1,252	1,885	3,136	5,779
1941	8	808	1,222	409	2,446	1,538	1,820	3,359	5,805
1942	4	717	786	417	1,924	889	1,635	2,524	4,448
1943	6	343	440	160	949	500	982	1,481	2,430
1944	1	164	352	50	567	415	844	1,259	1,826
1945	6	430	409	55	900	978	711	1,689	2,589
1946	1	589	199	8	797	901	1,031	1,932	2,729

[1] Western end to Port Burwell
[2] East of Port Burwell
[3] Fiscal year, July 1, 1896-June 30, 1897, in United States waters except Michigan
[4] Fall catch
[5] Estimated
[6] Less than 500 pounds (nil in 1923)
[7] Fall of 1924 and spring of 1925

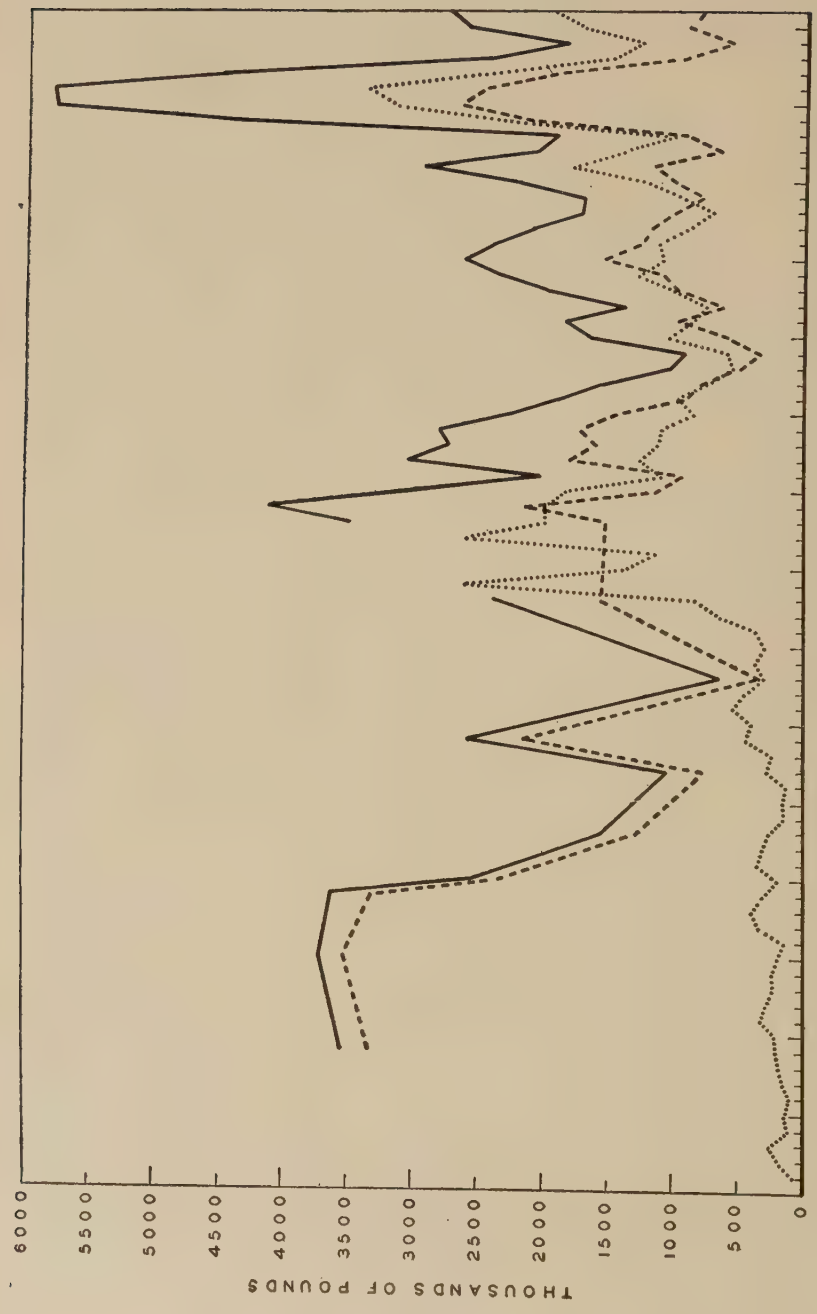

FIGURE 2.—Production of whitefish in Lake Erie, 1871–1946. United States, short dashes; Canada, dotted line; Entire lake, solid line.

ern portion of the lake (Michigan and Ohio) contributed 61.5 percent of the average annual total and the eastern area (Pennsylvania and New York) accounted for 38.5 percent of the United States production. The situation was reversed in 1921–1946 (data incomplete for 1925 which must be disregarded) when the Pennsylvania catch was dominant in 17 of 25

TABLE 4.—*Comparison of the average annual production (thousands of pounds) of whitefish in the different states and of the percentage contribution of each state to the total United States catch in Lake Erie in the periods, 1885–1920 and 1921–1946*

Period	Number of years	Item	State				Total
			Michigan	Ohio	Pennsylvania	New York	
1885–1920	[1]15	Average production...	161	914	545	128	1,749
		Percentage.....	9.2	52.3	31.2	7.3	.....
1921–1946	[2]25	Average production...	4	415	553	147	1,118
		Percentage.....	0.3	37.1	49.5	13.1	.....
Change in production, 1885–1920 to 1921–1946			−157	−499	8	19	−631

[1] Includes 1913 in which year data were available though defective for both Ohio and Pennsylvania
[2] Excludes 1925 in which year data were lacking for Pennsylvania and New York

years and that state, despite its short shoreline, accounted for 49.5 percent of the average annual total for the United States. The eastern portion of the lake contributed 62.6 percent of the United States catch as compared with 37.4 percent for the western region. Especially striking was the practical disappearance of the whitefish from State of Michigan waters.

Comparisons of the production in pounds in the various states during the periods 1885–1920 and 1921–1946 (Table 4) reveal only small changes in the averages for Pennsylvania and New York (increases of 8,000 and 19,000 pounds, respectively). Ohio's annual catch, however, averaged 499,000 pounds less in the years 1921–1946 than during the period 1885–1920 (decrease of 54.6 percent), while Michigan's average yield decreased 157,000 pounds or 97.5 percent. The difference of 631,000 pounds in the average total production (all United States waters) in the two periods can be traced entirely, therefore, to declines in the western portion of the lake.

The Canadian whitefish fishery of Lake Erie differed from that of United States waters in that production was low rather than high in the earlier years of the fishery. Although the catches of the earlier years exhibited a general upward trend (Table 3), production did not exceed 300,000 pounds before 1881, 400,000 pounds before 1899, or 500,000 pounds before 1901. The average annual yield of the 36 years of the early period, 1871–1906, was only 255,000 pounds. The level of production was much higher during the more recent years, 1907–1946. The average for the 40 years was 1,397,000 pounds or 5.48 times that of the earlier period. The catch, which did not fall below 500,000 pounds even once (lowest yield, 536,000 pounds in 1923), was less than a million pounds in 13 years, between 1 and 2 million pounds in 21 years, from 2 to 3 million pounds in 4 years, and above

3 million pounds in 2 years. The 1941 production of 3,359,000 pounds constituted a record for the Canadian waters of the lake.

The statistics of catch for both the western (western end of lake to Port Burwell) and eastern (east of Port Burwell) regions of the Canadian waters of Lake Erie for every year except 1923 in the 76-year period, 1871–1946, permit a more detailed study of changes in the center of the fishery (Table 5) than was possible with the United States data. Four

TABLE 5.—*Comparison of the average annual production (thousands of pounds) of whitefish in the western (west of Port Burwell) and eastern (east of Port Burwell) regions of the Canadian waters of Lake Erie and of the percentage contribution of each region to the Canadian total in five periods of years*

Period	Number of years	Item	Region of lake		Total
			Western	Eastern	
1871–1899	29	Average production	178	45	223
		Percentage	79.8	20.2	.....
1900–1909	10	Average production	234	443	677
		Percentage	34.6	65.4	.....
1910–1921	12	Average production	1,002	436	1,438
		Percentage	69.7	30.3	.....
1922–1946	[1]24	Average production	607	810	1,418
		Percentage	42.8	57.2	.....
1871–1921	51	Average production	383	215	598
		Percentage	64.0	36.0	.....
Increase in production, 1871–1921 to 1922–1946			224	595	820

[1] No data by region for 1923

rather distinct periods may be detected. The production of western Lake Erie dominated the Canadian total in every year but the first in the 29-year period, 1871–1899, and in the 12 years, 1910–1921. The eastern region usually was dominant in 1900–1909 (9 of 10 years) and 1922–1946 (20 of 24 years). The shift that occurred in 1922 corresponds to the change that took place in United States waters a year earlier. The fragmentary United States records (Table 3) offer no evidence that shifts in percentage contribution of different areas similar to those of Canadian waters occurred prior to 1921. The western United States waters almost invariably produced more whitefish than the eastern before 1921 and, except for 1946, always less after 1920.

Similarly a disagreement existed in the trend of production in the two countries during the earlier and later period of years. Whereas the annual production of the United States waters decreased in 1921–1946 by 631,000 pounds (Table 4) due entirely to a decrease in western waters (only a small increase took place in the eastern area), the Canadian annual yield increased during 1922–1946 by 820,000 pounds as the result of larger catches in both eastern and western waters (production was 1.58

times greater in western and 3.77 times greater in eastern waters). These discrepancies between the two countries suggest major shifts in fishing intensity for the whitefish.

The data on the total yield of whitefish in Lake Erie (combined United States and Canadian catch) may be divided into three general periods: (1) 1879–1890, when the United States yield was high but Canadian production was low; (2) 1893–1903, when the United States yield had declined from the earlier high level and the Canadian catch was still relatively low; and (3) 1908–1946, during which time the production of both areas fluctuated about the level that appears to be characteristic of the modern fishery. The years for which data were available for both countries in each of the periods are recorded in Table 6. For convenience, the terms, early, middle, and modern will be used in the discussion of average yields in the three periods.

TABLE 6.—*Production of whitefish (thousands of pounds) in Lake Erie and the percentages taken in United States and Canadian waters in three periods of the fishery*

Years	Item	Region of lake		Total
		United States	Canada	
1879, 1885, 1889, and 1890	Average production	3,133	225	3,358
	Percentage	93.3	6.7	.....
1893, 1897, 1899, and 1903	Average production	1,138	315	1,453
	Percentage	78.3	21.7	.....
1908 and 1913–1946	Average production	1,209	1,358	2,567
	Percentage	47.1	52.9	.....

As was indicated in the definition of the three periods, the decline from the early to the middle period may be attributed to a decrease in the United States catch whereas the increase from the middle to the modern period can be traced to a rise in the Canadian production. These changes in the output of the two areas brought about the increase of the percentage of the whitefish catch taken in Canada from 6.7 in the early period to 21.7 in the middle and 52.9 in the modern. The productions of the middle and modern periods (entire lake) expressed as percentages of the early yield are 43.3 and 76.4, respectively.

The yield of whitefish has fluctuated widely in the modern period—from 911,000 pounds in 1924 to 5,805,000 pounds (the all-time record) in 1941 (Table 3). Furthermore, production was consistently high or low over considerable numbers of years within the period (more than 2 million pounds, for example, in every year from 1913 to 1920; below 2 million pounds in every year from 1921 to 1928; in excess of 3 million pounds from 1939 to 1942). It is not believed, however, that the computation of averages for these shorter periods is desirable here.

The statistics of the period during which continuous data are available

for both United States and Canadian waters (1913–1946) are characterized by the close correlation between the annual productions in the two areas (see Fig. 2). The coefficient of correlation between the 1913–1946 United States and Canadian catches was 0.750. This high value suggests either that United States and Canadian fishermen are exploiting the same stock of whitefish or that the conditions that determine the fluctuations of the stocks are closely similar in United States and Canadian waters.

Strength of the Age Groups and Year Classes

The records of the age composition of the samples of the Lake Erie whitefish (Tables 7, 8, 9, and 10) show that relatively young fish (age-group IV and younger) ordinarily made up the bulk of the collections. Whitefish older than age-group IV can be termed abundant in only the 1927 collections from Sandusky. Age-group III was characteristically dominant in the gears important in the commercial production of whitefish—trap nets, pound nets, and large-mesh gill nets.[6] The dominance of age-group IV in the 1930 trap-net collection from Lorain provided the only exception.

In spite of the fact that apparently each year class is normally dominant in the catches of commercial gear for only one year (as the III group), the annual differences in the age composition of the samples of the Lake Erie whitefish were sufficiently great to indicate considerable variation from year to year in the success of reproduction. Although the data do not permit an exact ranking of the calendar years as to the strength of the year classes produced, certain year classes can be described safely as of greater or less than average strength. In the estimation of the relative strength of the year classes special attention should be given to the data for the trap-net samples (Table 7). This gear provided more than half of all the whitefish in the samples. Furthermore, trap-net samples were affected less by gear selectivity than were gill-net samples. The selective action of pound nets is similar to that of trap nets but relatively few whitefish were taken by that gear. Accordingly, statements as to the relative strength of the year classes will be based primarily on the data from trap-net collections, although some corroborating evidence will be obtained from collections from other gears.

It should be pointed out also that the relative abundance of age-groups I and II in samples taken from the spawning run provides rather unreliable evidence as to the strength of the year classes to which these age groups belonged. Whitefish of these age groups are predominantly immature (p. 243). Since practically no immature whitefish are on the breeding grounds during the spawning season, the representation of age-groups I and II must have been influenced by the percentage of individuals that attained maturity in the second or third year of life in different calendar years. The percentage of mature individuals in these younger age groups

[6] See p. 247 for comments relative to the capture of whitefish in small-mesh gill nets.

TABLE 7.—*Age and year-class composition of samples of Lake Erie whitefish taken by trap nets*

[Arranged according to port and year of capture]

Port and year of capture	Item	Year class																Average[1] or total
		1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	
Sandusky, O. 1927	Age group	XIII	..	..	X	IX	..	..	VI	V	..	III	II	I	..	..	..	3.50
	Number	1	..	..	1	2	..	..	5	20	..	41	31	2	..	..	..	103
	Percentage	1.0	..	..	1.0	1.9	..	..	4.9	19.4	..	39.8	30.1	1.9	..	..	..	....
Sandusky, O. 1928	Age group	XIV	XIII	..	XI	..	..	..	VII	VI	V	IV	III	II	I	..	..	3.26
	Number	1	2	..	2	..	..	..	1	4	2	59	142	54	1	..	..	268
	Percentage	0.4	0.7	..	0.7	..	..	..	0.4	1.5	0.7	22.0	53.0	20.2	0.4	..	..	.....
Sandusky, O. 1929	Age group	..	..	XIII	..	XI	X	..	..	VII	VI	V	IV	III	II	..	..	3.25
	Number	..	..	1	..	1	4	..	..	2	4	4	104	509	18	..	..	647
	Percentage	..	..	0.2	..	0.2	0.6	..	..	0.3	0.6	0.6	16.1	78.6	2.8	..	..	....
Lorain, O. 1929	Age group	..	..	..	..	XI	..	..	..	..	VI	V	IV	III	II	I	..	3.22
	Number	..	..	..	..	1	..	..	..	..	1	5	36	173	6	1	..	223
	Percentage	..	..	..	..	0.5	..	..	..	..	0.5	2.2	16.1	77.5	2.7	0.5	..	....
Conneaut, O. 1929	Age group	..	..	XIII	XII	..	X	..	VIII	VII	VI	V	IV	III	II	I	..	3.17
	Number	..	..	1	1	..	1	..	1	1	2	2	37	103	31	9	..	189
	Percentage	..	..	0.5	0.5	..	0.5	..	0.5	0.5	1.1	1.1	19.6	54.5	16.4	4.8	..	....
All ports 1929	Age group	..	..	XIII	XII	XI	X	..	VIII	VII	VI	V	IV	III	II	I	..	3.23
	Number	..	..	2	1	2	5	..	1	3	7	11	177	785	55	10	..	1,059
	Percentage	..	..	0.2	0.1	0.2	0.5	..	0.1	0.3	0.7	1.0	16.7	74.1	5.2	0.9	..	....
Lorain, O. 1930	Age group	..	..	..	..	..	..	X	IX	..	VII	VI	V	IV	III	II	I	3.55
	Number	..	..	..	..	..	..	1	1	..	2	6	15	141	67	52	1	286
	Percentage	..	..	..	..	..	..	0.3	0.3	..	0.7	2.1	5.3	49.3	23.5	18.2	0.3	....

[1] The first of each pair of figures in this column is the average number of annuli

TABLE 8.—*Age and year-class composition of samples of Lake Erie whitefish taken by large-mesh gill nets* (ca. *4¾ inches, stretched measure*)

[Arranged according to port and year of capture]

Port and year of capture	Item	Year class															Average[1] or total
		1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	
Sandusky, O. 1927	Age group	XIV	..	XII	XI	X	IX	VIII	VII	VI	V	IV	III	II	..	..	4.26
	Number	2	..	4	10	11	4	4	2	16	143	11	189	51	..	..	447
	Percentage	0.4	..	0.9	2.2	2.5	0.9	0.9	0.4	3.6	32.0	2.5	42.3	11.4	..	..	....
Erie, Pa. 1928	Age group	..	..	..	..	..	..	..	..	..	VI	V	IV	III	II	..	3.19
	Number	..	..	..	..	..	..	..	..	..	1	1	26	80	9	..	117
	Percentage	..	..	..	..	..	..	..	..	..	0.9	0.9	22.2	68.3	7.7	..	....
Erie, Pa. 1929	Age group	..	..	..	..	XII	..	..	..	..	VII	VI	V	IV	III	II	3.44
	Number	..	..	..	..	1	..	..	..	..	2	3	4	59	141	1	211
	Percentage	..	..	..	..	0.5	..	..	..	..	0.9	1.4	1.9	28.0	66.8	0.5	....
Sandusky, O. 1929	Age group	..	..	XIV	..	XII	..	X	..	..	VII	VI	V	IV	III	II	3.62
	Number	..	..	1	..	2	..	1	..	..	1	19	5	41	164	2	236
	Percentage	..	..	0.4	..	0.8	..	0.4	..	..	0.4	8.1	2.2	17.4	69.5	0.8	....

[1] The first of each pair of figures in this column is the average number of annuli

TABLE 9.—*Age and year-class composition of whitefish taken by pound nets off Erie, Pennsylvania, 1929*

Item	Year class					
	1913	1916	1917	1918	1919	1920
Age group	XVI	XIII	XII	XI	X	IX
Number	1	1	1	2	1	1
Percentage	0.4	0.4	0.4	0.8	0.4	0.4

Item	Year class					
	1921	1923	1924	1925	1926	1927
Age group	VIII	VI	V	IV	III	II
Number	1	5	3	59	172	5
Percentage	0.4	2.0	1.2	23.4	68.2	2.0

Total number	252
Average number of annuli	3.56

most probably varied with annual differences in the average length of the fish. Practically all collections of whitefish from Sandusky and Lorain were taken from the spawning run.

Two year classes, those of 1922 and 1926, were of more than average strength and the 1923 year class was exceptionally weak.

As age-group V in 1927, the 1922 year class provided by far the strongest V group of any collection (19.4 percent of the trap-net collections; 32.0 percent of the large-mesh gill-net collections). In only one other collection (Lorain in 1930) did the V group make up more than 5 percent of the total number of fish.

The 1926 year class may be considered strong because of its overwhelming dominance in the 1929 trap-net collections from Sandusky and Lorain[7] and because it provided in 1930 the only dominant IV group found in any of the samples. The evidence from the age composition of samples from the other gears is more difficult to evaluate. The 1926 year class as age-group III was relatively far stronger in the 1929 gill-net collection from Sandusky (Table 8) than was the III group of the 1927 gill-net collection (year class of 1924). At Erie, Pennsylvania, however, members of the III group were slightly more abundant in the large-mesh gill-net samples of 1928 (year class of 1925) than in those of 1929 (year class of 1926). The 1926 year class dominated the 1929 pound-net samples (Table 9) from Erie, but there are no collections from other years on which to base a comparison. The age composition of the collections from small-mesh gill nets (Table 10) provides some evidence, however, that the 1926 year class may have been of more than average strength in the eastern as well as in the western portion of Lake Erie. This year class as age-group II made up more than half (51.0 percent) of all whitefish taken

[7] The 1929 trap-net collection from Conneaut is not comparable with other trap-net collections since the samples were taken in early July (Table 1) at which time there is no evidence for a segregation of whitefish on the basis of maturity.

TABLE 10.—*Age and year-class composition of whitefish taken by small-mesh gill nets* (ca. *3 inches, stretched measure*) *off Erie, Pennsylvania, 1928 and 1929*

Year of capture	Item	Year class											Average[1] or total
		1915	1916	1919	1920	1921	1922	1924	1925	1926	1927	1928	
1928	Age group	XIII	XII	IX	VIII	VII	VI	..	III	II	I	..	1.85
	Number	1	1	1	1	1	1	..	17	125	97	..	245
	Percentage	0.4	0.4	0.4	0.4	0.4	0.4	..	7.0	51.0	39.6	..	....
1929	Age group	XIV	..	..	..	..	..	V	IV	III	II	I	2.09
	Number	1	..	..	..	..	..	1	14	43	42	70	171
	Percentage	0.6	..	..	..	..	..	0.6	8.2	25.1	24.6	40.9	....

[1] The first of each pair of figures in this column is the average number of annuli

in small-mesh gill nets in 1928, and in spite of the small size of the meshes (about 3 inches), comprised 25.1 percent (as age-group III) of the 1929 collection from this gear.

Conditions in 1926 seem to have been conducive to the survival of most if not all commercially important species of fish in Lake Erie. Earlier studies have demonstrated that 1926 saw the production of exceptionally strong year classes of yellow pikeperch, *Stizostedion v. vitreum*, blue pikeperch, *S. v. glaucum,* and saugers, *S. canadense,* (Deason, 1933), yellow perch (Jobes, 1933), freshwater drum or sheepshead (Van Oosten, 1938), and white bass (Van Oosten, 1942) as well as of whitefish.

The 1923 year class has been considered exceptionally weak because of its total absence as age-group IV in the 1927 trap-net collections and its great scarcity (only 2.5 percent) in the large-mesh gill-net collections of the same year. In no other trap-net samples did the IV group make up less than 16.1 percent of the entire sample and in no other large-mesh gill-net collection was the percentage of IV-group fish less than 17.4. Age-group IV contributed 23.4 percent of all whitefish in the 1929 pound-net collection from Erie.

There is no evidence that the strength of the year classes of 1924, 1925, and 1927 deviated widely from the normal. Year classes earlier than that of 1922 were represented by fish that were too old and year classes later than that of 1927 by fish that were too young for the numbers of individuals in the samples to provide a safe basis for the estimation of their relative strength. The rather large numbers of XI- and X-group whitefish in the 1927 collection from large-mesh gill nets possibly might be construed as evidence for strong year classes in 1916 and 1917.

Although fluctuations in the strength of year classes of fish have engaged the attention of numerous investigators, the underlying causes of these fluctuations continue to be largely a matter for speculation. It is agreed rather generally that the strength of a year class is determined early in its life history—probably at the egg and/or fry stage. It is becoming more apparent also that the nature of the conditions that determine the strength of year classes may vary widely in different environments and that in some situations the controlling factors may be extremely complex.

Meteorological factors as they affect conditions in the water are among those ordinarily considered to be of primary importance in the determination of the strength of year classes. Their effects conceivably may be direct (as in the destruction of eggs and fry by sudden changes of temperature or by heavy wave action resulting from high winds) or indirect (as in the control of the amount and kind of food available to young fish). There would be no point, however, in speculation as to the probable effects of this condition or that condition on the survival of young fish in Lake Erie. First, we need proof that a correlation between meteorological-limnological conditions and the strength of year classes actually exists. For the present, therefore, the best approach to the problem of fluctuations in the strength of year classes of fish in Lake Erie can be made through the careful exam-

ination of data for those years in which year classes are known to have been unusually strong or weak. If a particular factor exhibits an extreme condition in one direction in years of good survival and an extreme condition in the opposite direction in years of poor survival we have evidence that this factor may affect the strength of year classes. For the Lake Erie whitefish specifically we should attempt to find in what respects conditions were similar in 1922 and 1926 but contrasting to those of 1923.

The most critical period for whitefish might be expected to begin with the time of spawning (November and early December) and extend beyond the time of hatching in the next year (to May or June; the eggs hatch early in the spring). The simultaneous occurrence of strong year classes in 1926 of an autumn spawner (whitefish) and of spring or early-summer spawners (all three species of pikeperches, yellow perch, white bass, and freshwater drum) supports the belief that the strength of the year classes of whitefish may be determined by conditions at or near the time of hatching in the spring rather than by conditions during and immediately following the spawning season of the preceding autumn. On the other hand, the possibility must not be overlooked that the critical period for whitefish may be at or near the spawning period and that by coincidence favorable conditions obtained for whitefish in the fall of 1925 and for other species in the spring of 1926. (Year classes of autumn-spawning coregonids are assigned to the year in the spring of which they are hatched.)

If the occurrence of the strong year classes of 1922 and 1926 and the weak year class of 1923 were the result of annual fluctuations in meteorological-limnological conditions, those conditions should have been similar in the late months of 1921 and 1925 and/or in the early season of 1922 and 1926 and in contrast with those of 1922-1923. The available data failed to conform to this theoretical expectation.

The winter of 1925-1926 was exceptionally cold (temperature below the 1922–1930 average in every month but January in the period, October to April, inclusive).[8] The winter of 1921–1922, however, was warmer than average (every month but January above average, October to April). Of the same seven months of 1922–1923, three had temperatures above average and four had temperatures below the 1922–1930 mean. In this comparison, therefore, the seasons in which the strong year classes of 1922 and 1926 were produced provided the extreme conditions whereas the winter temperatures were intermediate in 1922–1923. Nor did the data for the months following April give indication that the strength of the year class may be correlated with temperatures in late spring and early summer.

Records of precipitation and the percentage of possible sunshine similarly failed to indicate a relationship between those factors and the strength of year classes. In 1926 the combined deficiency of rainfall in May and

[8] All statements given here concerning meteorological conditions are based on observations made at Sandusky, Ohio (Climatological Data for the United States by Sections, U. S. Weather Bureau). It has not been considered desirable to present the detailed tabulations that were prepared.

June was 3.42 inches (computed from the 1922–1930 average). Precipitation was below average in 1922 also (1.34-inch deficiency) but the significance of this similarity is made questionable by the fact that the May-June precipitation of 1923 as well was below average (0.48-inch deficiency). The excess percentage of possible sunshine in May and June 1926 was 20. A deficiency of sunshine occurred, however, in 1922 (total deficiency of 11 percent) while 1923 saw an excess of 13 percent in the same two months. It may be concluded, therefore, that dry sunshiny weather during the period of early growth was not associated with strong year classes of the whitefish. The same conclusion applies with respect to precipitation and sunshine in other months.

Negative results were obtained also from the examination of data on wind velocity (monthly maximum and mean). In general the winds were stronger in both the autumn and spring of 1921–1922 than in 1925–1926. (Most of the western end of the lake is usually frozen over in midwinter and hence little affected directly by winds at that period.) With respect to wind velocity, 1922–1923 and 1925–1926 resembled each other more closely than either resembled 1921–1922.

A particularly careful examination was made of the data on turbidity, a factor that has been held to be of major importance in the abundance of fish in Lake Erie. Agreement between 1922 and 1926 and disagreement between these two years and 1923 with respect to direction of deviation from mean conditions at Port Clinton and Huron [9] (Table 11) occurred in

TABLE 11.—*Deviations of turbidity (p.p.m.) from the 1922–1930 monthly mean (at Port Clinton and Huron, Ohio) during the first year of life of three year classes of Lake Erie whitefish*

[The November and December deviations are for the spawning period in the year preceding the one identifying the year class]

Month	Mean turbidity (1922–1930)	Deviation from average turbidity during first year of life		
		1922 (strong year class)	1923 (weak year class)	1926 (strong year class)
November	44	61	−12	− 3
December	42	32	−20	−10
January	32	6	−18	−24
February	24	− 6	11	−12
March	84	−22	58	−28
April	108	8	30	63
May	64	− 7	10	17
June	34	16	−15	− 9
July	23	10	−12	− 8
August	23	− 4	− 8	− 2
September	[1]30	6	−17	4
October	39	− 8	− 4	25

[1] Mean based on data for 8 years at Huron—no record for September 1924 at that locality

[9] The mean turbidities at these two ports provide our best available estimate of conditions on the spawning grounds of the whitefish. The combination of the records for Port Clinton and Huron seems justified by the high correlation ($r = 0.889$) between the monthly means over the 9-year period, 1922–1930. A value of $r = 0.798$ would be highly significant ($p = 0.01$).

three months. Turbidity was above average in February and March 1923 (poor year class) and below the mean in the same months in 1922 and 1926 (strong year classes). In September the turbidity was low in 1923 and slightly above average in 1922 and 1926. These data cannot be taken, however, as good evidence that the strength of the year classes of whitefish in Lake Erie is determined by turbidities in February, March, and September. First, the number of months (three) in which conditions in 1922 and 1926 were in agreement but in contrast with those of 1923 was precisely the same as would be expected on the basis of probability. Second, two of the months (February and March) fell in advance of the spawning time of most Lake Erie fish; yet all species, including those that spawned in April and later, that have been investigated had strong year classes in 1926. (We are not in position to comment on the strength of the 1922 and 1923 year classes for species other than the whitefish.) Third, the data for September are not impressive because the deviations from the mean were small both in 1922 and 1926 and particularly because it is generally conceded that the strength of the year classes is determined much earlier in the season. It may be concluded, therefore, that evidence is lacking for a correlation between turbidity and the strength of the year classes of the Lake Erie whitefish. This finding is in agreement with that of Van Oosten (1948) who showed that no clear-cut relationship existed between turbidity and the success of reproduction in Lake Erie fishes including the whitefish.

The failure to detect a correlation between meteorological-limnological conditions and fluctuations in the strength of the year classes of the Lake Erie whitefish should not be taken as proof that the weather at the time of spawning, embryological development, hatching, and early growth does not influence the success of reproduction. It is more probable that the factors which determine the strength of year classes are so numerous and have such complex interrelationships that it is not possible on the basis of present information to detect and evaluate the effect of any single one of them.

Age Composition of the Commercial Catch

All previous discussions of the age composition of the Lake Erie whitefish were based on random samples from commercial nets[10] including both legal-sized and undersized whitefish. It is of some value also to know the age composition of the marketable catch, that is, of fish of legal size. The size limit for whitefish in the United States waters of Lake Erie, except in the State of Michigan waters where production is negligible, is 1¾ pounds. It was determined from the general length-weight relationship (p. 234) that this weight is equivalent to a total length of 16.9 inches (standard length, 365 millimeters). By means of this "equivalent length" and length-frequency distributions of the age groups (tabulations not given here)

[10] The age composition of a few samples of whitefish from experimental trap nets did not differ from that of samples from standard commercial trap nets.

estimates have been made of the percentage of legal-sized whitefish in the different age groups of the various collections [11] (Table 12—see Tables 7, 8, 9, and 10 for actual numbers in the different age groups).

Not one whitefish in the samples was legal-sized as age-group I. The variation in the percentages of legal-sized whitefish in the older age groups may have been to some extent random. Some of the fluctuations, however, can be attributed to the selective action of the gear, to the time of capture in the season, and to the effects of annual fluctuations in growth rate. As an example of gear selection, large-mesh gill nets rather consistently took higher percentages of legal-sized II-group and III-group whitefish than did trap nets. On the other hand, the percentages of legal-sized whitefish were low in the collections from small-mesh gill nets. (The time of capture in the growing season may have contributed to these small

TABLE 12.—*Percentage of legal-sized whitefish in the various age groups*

[Arranged according to gear, port, and year of capture. All fish older than age-group V were legal-sized]

Gear	Port	Year of capture	Age group				
			I	II	III	IV	V
Trap nets	Sandusky, O.	1927	0.0	9.7	65.9	.....	100.0
		1928	0.0	9.3	81.0	100.0	100.0
		1929	...	22.2	82.5	96.2	100.0
		1927–1929	0.0	11.7	81.2	97.5	100.0
	Lorain, O.	1929	...	33.3	68.2	97.2	100.0
		1930	0.0	5.8	52.2	94.3	100.0
		1929–1930	0.0	8.6	63.8	94.9	100.0
	Conneaut, O.	1929	0.0	0.0	15.5	75.7	100.0
Large-mesh gill nets	Sandusky, O.	1927	...	17.6	81.5	100.0	99.3
		1929	...	50.0	90.9	100.0	100.0
		1927–1929	...	18.9	85.8	100.0	99.3
	Erie, Pa.	1928	...	33.3	91.2	96.2	100.0
		1929	...	0.0	87.9	100.0	100.0
		1928–1929	...	30.0	89.1	98.8	100.0
Pound nets	Erie, Pa.	1929	...	40.0	86.6	100.0	100.0
Small-mesh gill nets	Erie, Pa.	1928	0.0	0.8	35.3	.....	.....
		1929	0.0	7.9	46.5	92.9	100.0
		1928–1929	0.0	2.7	43.3	92.9	100.0

[11] This procedure was followed for estimating percentages of legal-sized fish despite the fact that records of weight were available for the individual specimens. Since, as will be brought out in later sections on the length-weight relationship, the condition (K) of whitefish varies rather widely with season and state of organs, percentages based on weights though absolutely descriptive of the individual collections might deviate considerably from "average" conditions. To illustrate the type of difficulty that can arise—female whitefish at or slightly above the minimum legal weight when ripe become undersized after they have spawned. The effects of sample bias traceable to season of capture or state of organs are smoothed out by the use of length frequencies and an "equivalent" legal length computed from a general length-weight equation that was based on the combination of fish of both sexes, in all stages of sexual development, and captured at different seasons of the year.

percentages—see Table 1). The percentages were rather high for the single pound-net collection although the selective action of this gear might be expected to resemble that of trap nets.

The trap-net collection from Conneaut in 1929 provides an outstanding example of the effect of the time of capture in the season on the percentage of legal-sized fish in the different age groups. In this collection which was taken July 9–12 early in the growing season [12] no II-group fish and only 15.5 and 75.7 percent, respectively, of age-groups III and IV had attained legal size. These percentages were far below those for trap-net samples taken in late autumn off Sandusky and Lorain. Selection of the larger fish on the basis of maturity also may have contributed to the higher percentages of legal-sized individuals in the spawning-run samples from Sandusky and Lorain.

The best example of the effects of annual fluctuations in growth rate on the percentage of legal-sized whitefish in the different age groups is offered by the 1930 collection from Lorain. The fact that the percentages were noticeably smaller for this collection than for the 1929 collection from the same port can be attributed in large measure to the excessively poor growth of whitefish in 1930 (p. 224).

In spite of the considerable variation in the percentages of Table 12 the general conclusions seem warranted that: no whitefish reach legal size in the second year of life; a small percentage become legal toward the end of the third year; a large majority reach legal size by the end of the fourth year; nearly all are legal-sized by the end of the fifth year; only rarely is a whitefish still undersized in the sixth year of life (one fish in the combined collections).

The age composition of the marketable catch of whitefish from gears important for the production of that species (trap nets, large-mesh gill nets, and pound nets—see Table 13) differed somewhat from the age composition of random samples from catches of the same gears (Tables 7, 8, and 9). Age-group I was entirely absent from the commercial catch and the representation of age-group II was reduced tremendously. The percentage representation of age-group III was usually reduced also (only three exceptions). Age-group III was most frequently dominant in the commercial catch as well as in the random samples. The percentage representation of the older age groups was always increased in the commercial catch.

The trap-net sample from Conneaut provided the only collection in which different age groups dominated the random sample and the commercial catch. Age-group III was dominant in the random sample (54.5 percent). Only 15.5 percent of these III-group fish were of legal size, however. As a result this age group made up only 30.2 percent of the commercial catch as compared with a percentage of 52.8 for age-group IV. (The dominance of age-group IV in the 1930 commercial catch of Lorain was

[12] The small amount of marginal growth outside the last visible annulus proved that these fish were captured relatively early in the growing season.

the result of the strong 1926 year class—see p. 195.) The age composition of the July collection from Conneaut indicates that III-group whitefish ordinarily do not become dominant in the commercial catch until late in the fourth growing season. Apparently each year class normally is dominant in the commercial fishery about one year but this year extends into two years of life—the latter part of the fourth year and the early part of the fifth.

TABLE 13.—*Age composition by number of legal-sized whitefish in samples from trap nets, large-mesh gill nets, and pound nets*

[Percentages are given in parentheses]

Port	Year of capture	Age group					Total
		II	III	IV	V	> V	
Trap nets							
Sandusky, O.	1927	3 (5.1)	27 (45.8)	... ...	20 (33.9)	9 (15.2)	59 ...
	1928	5 (2.6)	115 (60.2)	59 (30.9)	2 (1.1)	10 (5.2)	191 ...
	1929	4 (0.7)	420 (77.8)	100 (18.5)	4 (0.7)	12 (2.3)	540 ...
Lorain, O.	1929	2 (1.2)	118 (72.9)	35 (21.6)	5 (3.1)	2 (1.2)	162 ...
	1930	3 (1.5)	35 (17.9)	133 (67.8)	15 (7.7)	10 (5.1)	196 ...
Conneaut, O.	1929	... ...	16 (30.2)	28 (52.8)	2 (3.8)	7 (13.2)	53 ...
Large-mesh gill nets							
Sandusky, O.	1927	9 (2.4)	154 (41.7)	11 (3.0)	142 (38.5)	53 (14.4)	369 ...
	1929	1 (0.5)	149 (67.7)	41 (18.6)	5 (2.3)	24 (10.9)	220 ...
Erie, Pa.	1928	3 (2.9)	73 (70.9)	25 (24.2)	1 (1.0)	1 (1.0)	103 ...
	1929	... ...	124 (64.2)	59 (30.6)	4 (2.1)	6 (3.1)	193 ...
Pound nets							
Erie, Pa.	1929	2 (0.9)	149 (65.9)	59 (26.1)	3 (1.3)	13 (5.8)	226 ...

LENGTH-FREQUENCY DISTRIBUTION OF THE AGE GROUPS

The length-frequency distributions of Table 14 have been based on the combination of the data for all age groups of late-summer and autumn collections employed for the study of growth; that is, the age groups listed on pages 183–184 as not represented adequately and the entire collection

from Conneaut, Ohio, (taken in the first half of July) were excluded.

The combination of the data for samples of different gears, ports, and years of capture increased the dispersion of the frequencies considerably but extended the range surprisingly little beyond those found in the individual collections except in those age groups in which some particular sample contained individual fish that had grown exceptionally rapidly or slowly (as, for example, the III-group fish at 270–279 and 500–509 millimeters and the V-group fish at 310–319 and 530–539 millimeters). Although the length-frequency distributions of age groups in more nearly homogeneous samples might be expected ordinarily to be more compact and to have somewhat smaller total ranges, the data of Table 14 are of value in bringing out the approximate total range of length and the degree of overlap of the length frequencies of age groups of whitefish captured in late season over a period of years.

The modal lengths of age-groups I and II probably might stand out in the length-frequency distribution of most random samples of the population. Beyond age-group II, however, length is an exceedingly poor index of age. The overlap at 530-539 millimeters, for example, involved a range of 12 age groups (V to XVI inclusive—age-group XV not listed in the table) of which 9 actually were represented. Similarly, at 500-509 the range was 10 age groups (III to XII) of which 5 actually were present. Not less than three age groups were represented at all intervals between 340 and 559 millimeters (fish were scarce above the latter length), and at least four age groups were present at every interval between 390 and 549 millimeters.

The extensive overlap of the length-frequency distributions of the age groups is the combined result of the decline in growth rate in the later years of life (note the small differences between the average lengths of successive age groups beyond age-group III) and the extremely large range of length in the individual age groups. Age-group III had the greatest range of length with an extreme of 239 millimeters, standard length, or 10.6 inches, total length, (limits of the intervals represented). The range was nearly as large for age-group V (229 millimeters; 10.1 inches). The length ranges were not so great in the remaining age groups but were nevertheless fairly large in most, especially in those that were well represented.

The III-group whitefish, which have been shown to be normally dominant in both the random samples and in the commercial catch of the late season, were most abundant over the interval of approximately 16.2–19.0 inches (350–409 millimeters). Age-group IV which occasionally may be dominant in the late season (as at Lorain in 1930) was best represented at about 17.6–19.8 inches (380–429 millimeters).

In these combined late-season collections all I-group and 97 percent of the II-group whitefish [13] were below the length of 16.9 inches (365 milli-

[13] In Table 14 age-groups I and II were represented exclusively by collections from Erie, Pennsylvania.

TABLE 14.—*Length-frequency distribution of the age groups of Lake Erie whitefish*

[Based on the combination of all collections employed for the study of growth, except the 1929 collection from Conneaut, Ohio]

Standard length (millimeters)	Equivalent midpoint (inches)	Age group														
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XVI
200–209	9.5	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
210–219	10.0	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..
220–229	10.5	9	..	..	..	..	..	..	..	..	..	..	..	..	..	..
230–239	10.9	21	..	..	..	..	..	..	..	..	..	..	..	..	..	..
240–249	11.4	33	..	..	..	..	..	..	..	..	..	..	..	..	..	..
250–259	11.9	29	3	..	..	..	..	..	..	..	..	..	..	..	..	..
260–269	12.3	30	3	..	..	..	..	..	..	..	..	..	..	..	..	..
270–279	12.8	24	12	1	..	..	..	..	..	..	..	..	..	..	..	..
280–289	13.3	14	14	..	..	..	..	..	..	..	..	..	..	..	..	..
290–299	13.7	3	22	1	..	..	..	..	..	..	..	..	..	..	..	..
300–309	14.2	1	33	1	..	..	..	..	..	..	..	..	..	..	..	..
310–319	14.7	..	29	2	..	1	..	..	..	..	..	..	..	..	..	..
320–329	15.1	..	29	2	..	..	..	..	..	..	..	..	..	..	..	..
330–339	15.6	..	17	14	..	..	..	..	..	..	..	..	..	..	..	..
340–349	16.1	..	6	52	2	..	..	..	..	..	..	..	..	..	..	..
350–359	16.4	..	7	108	7	..	..	..	..	..	..	..	..	..	..	..
360–369	16.9	..	4	231	12	2	..	..	..	..	..	..	..	..	..	..
370–379	17.3	..	2	303	37	..	..	..	..	..	..	..	..	..	..	..
380–389	17.8	..	..	270	62	2	..	..	..	..	..	..	..	..	..	..
390–399	18.2	..	1	206	85	9	..	..	..	..	..	..	..	..	..	..
400–409	18.7	..	..	100	103	15	2	..	..	..	..	..	..	..	..	..
410–419	19.2	..	..	59	69	14	2	..	..	..	..	..	..	..	..	..
420–429	19.6	..	..	21	55	36	4	..	..	..	..	..	..	..	..	..
430–439	20.1	..	..	5	36	42	4	..	..	..	..	..	..	..	..	..
440–449	20.6	..	..	5	20	40	6	..	..	..	..	..	..	..	..	..
450–459	20.8	..	..	1	5	22	16	2	..	..	..	..	..	..	..	..
460–469	21.3	..	..	2	2	16	10	2	..	1	..	..	..	..	..	..
470–479	21.8	..	..	..	2	2	13	1	1	..	1	..	..	..	..	..
480–489	22.2	..	..	..	1	1	3	3	1	1	4	2	..	..	..	..
490–499	22.7	..	..	..	..	..	3	1	..	1	1	..	..	..	..	..
500–509	22.9	..	..	1	..	..	2	1	..	..	..	2	2	..	..	..
510–519	23.4	..	..	..	..	..	..	1	2	1	6	4	..	1	..	..
520–529	23.8	..	..	..	..	..	..	..	..	3	3	1	..	1	..	..
530–539	24.3	..	..	..	..	1	..	..	1	1	3	4	2	1	1	1
540–549	24.8	..	..	..	..	..	..	..	..	1	1	2	..	1	3	..
550–559	25.2	..	..	..	..	..	..	..	1	..	..	1	4	..	..	..
560–569	25.7	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..
570–579	26.1	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..
580–589	26.6	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
590–599	27.0	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..
600–609	27.5	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
610–619	27.9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
620–629	28.4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
630–639	28.8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Average standard length		256	311	379	404	433	458	479	513	513	516	522	543	550	554	584
Average total length		12.0	14.5	17.5	18.7	20.0	21.0	22.0	23.3	23.3	23.5	23.8	24.7	25.0	25.2	26.6
Total number		167	182	1,385	498	203	65	11	6	9	20	16	10	7	5	2
Percentage illegal		100	97	21	3	1	0	0	0	0	0	0	0	0	0	0

meters) which corresponds to the minimum legal weight of 1¾ pounds. The percentage of undersized whitefish decreased to 21 in age-group III, 3 in age-group IV, and 1 in age-group V. All fish older than age-group V were legal-sized.

The total lengths in inches given in Table 14 and in the preceding text were converted from standard lengths by means of factors listed in Table 15. The table contains also factors for the conversion of total lengths in inches to standard lengths in millimeters and for conversions between total and standard length without change in the unit of measurement. The relative length of the tail of the Lake Erie whitefish decreases with increase in the length of the fish. Van Oosten (1939) observed a similar change in the relative length of the caudal fin of the Lake Huron whitefish.

TABLE 15.—*Factors for conversions etween total (T.L.) and standard (S.L.) lengths of Lake Erie whitefish at different sizes*

[The data are based on fish taken in different parts of Lake Erie over the period 1927–1929]

Standard length (millimeters)	Number of fish	Conversion factor			
		T.L. to S.L. (no change of units)	S.L. to T.L. (no change of units)	T.L. (inches) to S.L. (millimeters)	S.L. (millimeters) to T.L. (inches)
< 350	42	0.843	1.186	21.41	0.0467
350–449	1,050	0.851	1.175	21.62	0.0463
450–499	36	0.858	1.166	21.79	0.0459
> 499	17	0.866	1.155	22.00	0.0455

AVERAGE LENGTHS AND WEIGHTS OF THE AGE GROUPS

Comparisons of the average lengths and weights of male and female whitefish [14] indicate that the females were larger than the males of the same age and taken off the same port (Table 16). Among the best represented age groups in the Sandusky collection (age-groups III to VI, inclusive) the females averaged 0.4 to 0.6 inch (8 to 15 millimeters) longer than the males. The advantages of the females in average weight in the same age groups ranged from 0.03 to 0.43 pound (0.01 to 0.20 kilogram). Females averaged the larger in age-groups VII and VIII also but males were the larger in age-groups X, XI, and XII. There were relatively few fish, however, in age groups older than the VI group.

Comparisons of the average lengths of males and females of age-groups I and II from Sandusky (and Lorain as well) would lack significance even if more specimens were available. Practically all collections from these ports were taken from the spawning run which tends to be made up almost entirely of mature fish. Consequently the averages for these age groups would be affected by sex differences in the size at which maturity is first attained. (Males appear to become mature at an earlier age than do

[14] Records of sex were lacking for all whitefish from Conneaut and for a large part of the collections from Erie.

TABLE 16.—*Total length (inches) and weight (pounds) of the age groups of Lake Erie whitefish according to sex and port*

[The collections of different years have been combined]

Port	Sex	Item	Age group													
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Sandusky, O.[1]	Male.....	Total length....	13.4	15.9	17.5	18.4	20.0	20.8	21.0	21.9	..	23.7	25.2	25.0	..	..
		Weight.....	0.84	1.43	1.88	2.24	2.99	3.41	3.56	4.38	..	5.28	6.84	6.72	..	..
		Number of fish..	2	79	507	68	106	24	3	1	..	5	1	1	..	..
	Female...	Total length....	..	16.0	18.1	18.9	20.4	21.3	22.4	23.0	23.0	23.1	23.7	24.4	24.8	24.7
		Weight.....	..	1.38	2.31	2.64	3.02	3.80	4.22	5.13	4.24	4.50	5.45	5.52	6.24	6.16
		Number of fish..	..	1	115	60	57	20	3	3	6	11	11	5	3	4
Lorain, O.	Male.....	Total length....	..	15.8	17.1	18.1	19.7	20.3	22.2	..	..	23.2	22.3	..	..	..
		Weight.....	..	1.40	1.80	2.16	2.82	3.16	4.44	..	..	5.66	4.12	..	..	..
		Number of fish..	..	53	223	97	10	2	1	..	..	1	1	..	..	..
	Female...	Total length....	14.3	16.0	17.7	18.6	20.3	21.0	22.0	..	23.7	..	..	..	..	..
		Weight.....	1.31	1.42	2.18	2.62	3.48	3.49	3.94	..	6.44	..	..	..	..	..
		Number of fish..	1	3	17	80	10	5	1	..	1	..	..	..	..	..
Erie, Pa.	Male.....	Total length....	12.1	14.6	17.8	18.2	..	..	..	..	..	..	..	..	..	..
		Weight.....	0.58	1.05	2.11	2.47	..	..	..	..	..	..	..	..	..	..
		Number of fish..	43	41	30	6	..	..	..	..	..	..	..	..	..	..
	Female...	Total length....	12.4	14.8	18.2	20.0	..	21.5	22.2	..	..	..	..	..	..	..
		Weight.....	0.60	1.07	2.31	3.22	..	4.30	4.33	..	..	..	..	..	..	..
		Number of fish..	56	37	20	8	..	3	1	..	..	..	..	..	..	..
All ports[2]	Male.....	Total length....	12.1	14.6	17.4	18.2	20.0	20.8	21.3	21.9	..	23.6	23.8	25.0	..	..
		Weight.....	0.58	1.05	1.87	2.20	2.98	3.39	3.78	4.38	..	5.34	5.48	6.72	..	..
		Number of fish..	43	41	760	171	116	26	4	1	..	6	2	1	..	..
	Female...	Total length....	12.4	14.8	18.1	18.8	20.4	21.3	22.3	23.0	23.1	23.1	23.7	24.4	24.8	24.7
		Weight.....	0.60	1.07	2.30	2.66	3.09	3.80	4.19	5.13	4.55	4.50	5.45	5.52	6.24	6.16
		Number of fish..	56	37	152	148	67	28	5	3	7	11	11	5	3	4

[1] Averages for age groups younger than the V group were based on trap-net collections only

[2] Averages for age-groups I and II were based on Erie collections only

females—p. 245.) Possibly sex differences in the average size of III-group and even of IV-group whitefish were affected slightly by selection according to size at first maturity.

Female whitefish of age-groups III, IV, and V from Lorain averaged 0.5 to 0.6 inch (11 to 13 millimeters) longer than male whitefish of corresponding age, and had a weight advantage of 0.38 to 0.66 pound (0.17 to 0.30 kilogram).

The data for whitefish from Erie demonstrate that sex differences in the average size of the age groups are not confined to spawning-run samples.[15] Females of the best represented age groups (I to III) were 0.2 to 0.4 inch (4 to 9 millimeters) longer and 0.02 to 0.20 pound (0.01 to 0.09 kilogram) heavier than males of the same age. It should be noted, however, that sex differences in the size of III-group fish were smaller in the collections from Erie than in the spawning-run samples from Sandusky and Lorain. The averages for age-groups I and II suggest that sex differences in average size may be established rather early in life. In the weakly represented IV group from Erie the females averaged much larger than the males (1.8 inches or 39 millimeters longer; 0.75 pound or 0.34 kilogram heavier).

The advantages of the females over males of the same age were much the same in the combined samples as in the collections for the individual ports.

A tabulation of the average lengths and weights of the age groups with the data for the sexes combined (and, of course, including the considerable numbers of fish for which records of sex were lacking) appears to be desirable in spite of the known sex differences in growth rate (Table 17.) The averages of Table 17 reveal considerable differences in the average size of the age groups in collections from the several ports. Although differences in the normal rate of growth of whitefish from these ports conceivably may have contributed to the variation in the average size of the age groups, much of this variability and possibly most or all of it can be attributed to other causes.

The small average size of the younger age groups in the Conneaut collection, for example, can be explained to a large extent as the result of the time of capture in the growing season (first half of July as compared to late summer, autumn, or early winter for the other collections). At the higher ages (older than age-group V) when the time of capture in the season should have little effect on the average size of the age groups the average lengths and weights of the Conneaut fish ordinarily were not the lowest.

Annual fluctuations in growth rate account, in part at least, for the tendency of the whitefish from Lorain to average small. As will be brought out in a later section, the growth of whitefish was considerably below average in 1929 and was poorer in 1930 than in any other year of the period, 1924–1930. Thus all fish taken off Lorain (captured in 1929 and

[15] The only fish taken in November were immature fish captured at a distance from the spawning grounds.

TABLE 17.—*Total length (inches) and weight (pounds) of the age groups of Lake Erie whitefish, sexes combined (including fish for which records of sex were lacking), according to port*

[The collections of different years have been combined]

Port	Item	Age group														
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XVI
Sandusky, O.[1]	Total length	12.6	15.9	17.6	18.8	20.1	21.0	21.7	22.9	23.0	23.3	23.8	24.5	25.1	24.7	..
	Weight	0.70	1.42	1.98	2.53	2.98	3.55	3.89	4.94	4.24	4.70	5.48	5.72	6.74	6.16	..
	Number of fish	3	103	692	163	174	48	6	4	6	17	13	6	4	4	..
Lorain, O.	Total length	12.3	15.8	17.2	18.3	20.0	20.7	22.1	..	23.7	23.2	22.3	..	..	..	..
	Weight	0.84	1.40	1.82	2.36	3.15	3.40	4.19	..	6.44	5.66	4.12	..	..	..	..
	Number of fish	2	58	240	177	20	7	2	..	1	1	1	..	..	..	..
Conneaut, O.	Total length	8.5	12.9	15.9	17.5	18.4	20.9	22.4	22.5	..	23.2	..	24.7	24.6	..	..
	Weight	0.19	0.71	1.42	1.98	2.28	3.41	4.25	4.30	..	4.80	..	6.14	6.84	..	..
	Number of fish	9	31	103	37	2	2	1	1	..	1	..	1	1	..	..
Erie, Pa.	Total length	12.0	14.5	17.7	19.0	19.7	21.4	22.6	24.7	24.2	25.3	24.7	25.0	24.9	27.3	26.6
	Weight	0.56	1.06	2.12	2.70	3.06	4.18	4.34	6.40	6.69	6.30	5.38	6.88	7.01	9.88	8.82
	Number of fish	167	182	453	158	9	10	3	2	2	2	2	4	3	1	2
Sandusky, Lorain, and Erie[2]	Total length	12.0	14.5	17.5	18.7	20.0	21.0	22.0	23.3	23.3	23.5	23.8	24.7	25.0	25.2	26.6
	Weight	0.56	1.06	2.00	2.52	3.00	3.63	4.07	5.43	5.03	4.91	5.38	6.18	6.86	6.90	8.82
	Standard length[3]	256	311	379	404	433	458	479	513	513	516	522	543	550	554	584
	Weight[3]	0.25	0.48	0.91	1.14	1.36	1.65	1.84	2.46	2.28	2.23	2.44	2.80	3.11	3.13	4.00
	Number of fish	167	182	1,385	498	203	65	11	6	9	20	16	10	7	5	2

[1] Averages for age groups younger than the V group were based on trap-net collections only
[2] Averages for age-groups I and II were based on Erie collections only
[3] Length in millimeters; weight in kilograms

1930) had been subjected to at least one year of poor growth and those captured in 1930 had suffered two years of poor growth. Some of the collections from other localities were affected by the poor growth of 1929 but none by the exceptionally unfavorable growth conditions of 1930.

The average sizes of the younger age groups of both the Sandusky and Lorain collections probably were increased by selection on the basis of maturity (p. 183), with the values for age-groups I and II distorted most severely and those for age-groups III and IV influenced to a lesser extent (the latter possibly but little or not at all).

As was mentioned earlier (p. 184), the average size of individuals of the same group but taken by different gears varied considerably in the collections from Erie, Pennsylvania. Although a combination of the data for the collections from all gears was considered to offer the most reliable information available, the possibility remains that the averages for certain of the age groups from this port may have been distorted by gear selection.

The conclusion seems warranted that the differences in the average size of the age groups of whitefish from different ports indicated in Table 17 cannot be taken as proof that the growth of the whitefish varies significantly in the several regions of the lake.[16] Consequently the grand averages at the bottom of the table seem to provide the most reliable data available on the average lengths and weights of the age groups of Lake Erie whitefish. In the computation of these averages the data for the Conneaut collections and for age-groups I and II of the Sandusky and Lorain collections were excluded.

The average lengths of the age groups increased rapidly from the I group to the III group and thereafter increased fairly consistently (only exception provided by the equal lengths of age-groups VIII and IX) but slowly. Among the older groups the extent of the increases varied somewhat irregularly. The III group (near the end of the fourth growing season) was the youngest age group whose grand average length exceeded 16.9 inches or 365 millimeters (the length corresponding to the minimum legal weight of 1¾ pounds). Only age-group XII and older fish had average lengths in excess of 2 feet (528 millimeters).

The average weights of the age groups increased consistently and fairly rapidly up to age-group VIII. Beyond that age group the upward trend in the average weights was interrupted by irregularities (decreases in age-groups IX and X; average weights of age-groups IX to XI all less than that of the VIII group). Age-group III was the youngest in which the average weight exceeded the legal size limit (1¾ pounds or 0.79 kilogram). The average weight of 4 pounds (1.81 kilograms) was first attained by the VII group and only age-groups XII and older averaged more than 6 pounds (2.72 kilograms).

[16] The problem of possible differences in the growth of whitefish from the several localities will receive further attention in the next section where additional evidence (based on calculated lengths) will be adduced in support of the belief that much of the observed variation cannot be interpreted as indicative of permanent significant differences in growth rate.

Calculated Growth

Growth in length.—The study of the calculated growth of the Lake Erie whitefish will be confined to the average calculated lengths of the males and females and of the sexes combined as determined from the combination of the data for all age groups [17] in all years' collections from each port and from all ports combined (Table 18).[18] It is not believed that the additional information to be gained is sufficiently great to justify the tremendous expansion of tabular material that would be required to show the calculated growth history of each age group of the different years' collections from the various ports. Data concerning the growth of certain individual age groups will be employed, however, in the later section on annual fluctuations in growth rate.

The calculated lengths of the female whitefish were consistently greater than those of males in the collections from the same port (only exception provided by the equal second-year lengths of the sexes in the Sandusky collections). These sex differences ranged from 0.1 to 0.3 inch in the first year of life, from nil to 0.3 inch in the second year, and from 0.2 to 0.5 inch in the third. In the later years of life the calculated lengths of the females were characteristically in the neighborhood of 0.5 inch greater than those of males in the same year of life. Sex differences in growth in length in the combined collections resembled those in the individual samples. Observations made previously (p. 206) as to the possible effects of selection, correlated with sex differences in the size at first maturity, on the determination of the average sizes of the age groups of males and females apply also to sex differences in calculated length.

Since records of sex were available for relatively few of the whitefish taken off Erie and for none of those in the Conneaut samples and since the sex differences in calculated lengths were generally small (particularly in relation to the actual size of this rather large fish) the best comparisons of growth in the collections from different ports appear to be those based on the combined data for the sexes.

The first-year and second-year calculated lengths of the whitefish from Erie were equal to or only slightly larger than those of the fish from Lorain and Sandusky, although they were considerably larger than the lengths of the Conneaut specimens. In the later years of life, however, the Erie whitefish were distinctly longer than fish of corresponding age from the other ports. The minimum advantage of the Erie fish (that is, the advantage over the Sandusky specimens) increased from 0.2 inch at the end of the third

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[17] Certain of the younger age groups were excluded as unrepresentative—see section on materials and methods.

[18] The average calculated lengths of Table 18 for the collections from the different ports were the grand average calculated lengths in the earlier years of life; in the later years the calculated lengths were determined by the successive addition of the average annual increments of length. The summation of the average annual increments was employed exclusively in the determination of the general growth (based on combined data from all ports). This summation introduced some discrepancies in the table but these are trifling in relation to the value of the smoothing from the differences.

TABLE 18.—*Calculated total length (inches) of the Lake Erie whitefish according to sex and port*

[The collections of different years have been combined. In the bottom section annual increments of length have been included. Numbers of specimens in parentheses]

Port	Sex	Calculated length at end of year of life															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sandusky, O.	Male	6.8 (716)	12.7 (716)	16.0 (716)	18.0 (209)	19.4 (141)	20.6 (35)	21.3 (11)	21.9 (8)	22.8 (7)	23.2 (7)	23.5 (2)	24.0 (1)	.. ..	.. ..	.. ..	.. ..
	Female	6.9 (298)	12.7 (298)	16.2 (298)	18.4 (183)	20.0 (123)	20.9 (66)	21.8 (46)	22.4 (43)	23.0 (40)	23.5 (34)	24.0 (23)	24.4 (12)	24.8 (7)	25.2 (4)	.. ..	.. ..
	Both	6.8 (1,137)	12.7 (1,137)	16.1 (1,137)	18.2 (445)	19.7 (282)	20.7 (108)	21.4 (60)	22.1 (54)	22.9 (50)	23.3 (44)	23.8 (27)	24.2 (14)	24.5 (8)	24.9 (4)	.. ..	.. ..
Lorain, O.	Male	6.9 (335)	12.6 (335)	15.8 (335)	17.5 (112)	18.7 (15)	19.6 (5)	20.5 (3)	21.0 (2)	21.8 (2)	22.2 (2)	22.7 (1)	.. ..	.. ..	.. ..	.. ..	.. ..
	Female	7.1 (114)	12.9 (114)	16.3 (114)	18.1 (97)	19.3 (17)	20.1 (7)	20.7 (2)	21.5 (1)	21.9 (1)	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
	Both	7.0 (449)	12.7 (449)	15.9 (449)	17.7 (209)	18.9 (32)	19.8 (12)	20.6 (5)	21.2 (3)	21.8 (3)	22.3 (2)	22.8 (1)	.. ..	.. ..	.. ..	.. ..	.. ..
Conneaut, O.	Both	6.5 (180)	11.9 (180)	15.2 (149)	17.3 (46)	18.8 (9)	19.9 (7)	20.6 (5)	21.3 (4)	21.8 (3)	22.4 (3)	22.9 (2)	23.3 (2)	23.5 (1)	.. ..	.. ..	.. ..
Erie, Pa.	Male	6.9 (120)	12.7 (77)	16.2 (36)	18.6 (6)	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
	Female	7.2 (125)	12.9 (69)	16.5 (32)	18.9 (12)	20.7 (4)	21.7 (4)	22.3 (1)	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
	Both	7.0 (1,000)	12.8 (833)	16.3 (651)	18.6 (198)	20.2 (40)	21.3 (31)	22.3 (21)	22.9 (18)	23.5 (16)	24.1 (14)	24.7 (12)	25.2 (10)	25.8 (6)	26.1 (3)	26.4 (2)	26.7 (2)
All ports	Male	6.8 6.8 (1,171)	12.7 5.9 (1,128)	15.9 3.2 (1,087)	17.8 1.9 (327)	19.3 1.5 (156)	20.4 1.1 (40)	21.1 0.7 (14)	21.8 0.7 (10)	22.6 0.8 (9)	22.9 0.3 (9)	23.3 0.4 (3)	23.8 0.5 (1)	.. ..	.. ..	.. ..	.. ..
	Female	7.0 7.0 (537)	12.8 5.8 (481)	16.3 3.5 (444)	18.4 2.1 (292)	19.9 1.5 (144)	20.8 0.9 (77)	21.7 0.9 (49)	22.4 0.7 (44)	22.9 0.5 (41)	23.4 0.5 (34)	23.9 0.5 (23)	24.3 0.4 (12)	24.7 0.4 (7)	25.1 0.4 (4)	.. ..	.. ..
	Both	6.9 6.9 (2,766)	12.7 5.8 (2,599)	16.1 3.4 (2,386)	18.1 2.0 (898)	19.6 1.5 (363)	20.7 1.1 (158)	21.4 0.7 (91)	22.1 0.7 (79)	22.8 0.7 (72)	23.2 0.4 (63)	23.7 0.5 (42)	24.2 0.5 (26)	24.6 0.4 (15)	25.0 0.4 (7)	25.3 0.3 (2)	25.6 0.3 (2)
	Both[1]	147 147	271 124	344 73	391 47	423 32	447 24	466 19	482 16	497 15	510 13	521 11	531 10	541 10	550 9	556 6	563 7

[1] Standard lengths and increments of length in millimeters

year of life to 0.9 inch at the end of the seventh, decreased in the eighth and ninth years and then rose to become an inch or more in the twelfth and fourteenth years. The maximum advantage of the Erie whitefish (the advantage over the Conneaut or Lorain fish) increased from 1.1 inches at the end of the third year of life to 1.7 inches at the end of the seventh, ranged from 1.7 to 1.9 inches in the eighth to twelfth years and rose to 2.3 inches in the thirteenth. The calculated lengths of the Sandusky whitefish, although smaller than those of the Erie individuals, exceeded the lengths of the Conneaut and Lorain specimens in all years of life beyond the second. The advantage of the Sandusky whitefish over those from Conneaut and Lorain (computed always with respect to the population with the higher calculated length in each particular year of life) rose from 0.2 inch at the end of the third year of life to 0.8 inch at the end of the fifth and thereafter (sixth to thirteenth year inclusive) fell within the limits of 0.8 to 1.1 inches. The calculated lengths of whitefish from Conneaut in the first four years of life were from 0.3 to 0.8 inch less than the lowest corresponding calculated lengths of the collection from any other port. In the fifth and later years of life, however, the lengths of whitefish from Conneaut and Lorain were the same or differed by only 0.1 inch.

Some of the variations among the calculated growth histories of whitefish taken off different ports were sufficiently large and of sufficiently consistent occurrence to indicate the existence of real differences in the growth rate of whitefish in the collections from the various ports. It does not necessarily follow, however, that similar and permanent significant differences exist in the growth rate of whitefish in these regions of Lake Erie since the samples were affected by selection originating from certain sources and by factors that might produce discrepancies in growth rate that were either apparent or transitory.

Of the several factors suggested in the preceding section as contributing to the observed differences from port to port in the average lengths and weights of the age groups, all (except, of course, the time of capture in the growing season) may be held to have affected the calculated lengths also. Selection on the basis of maturity, gear selectivity, and annual fluctuations in growth rate in conjunction with differences in the years of capture may be expected to have distorted the data on calculated lengths in much the same way that they influenced the determination of the average size of the age groups.

Lee's phenomenon also may have contributed to the observed differences in the calculated length of whitefish in the collections from different ports. For reasons outlined previously (p. 184) all age groups were employed in the calculation of the general growth data for the Erie collection whereas certain age groups were excluded from the computations for other collections (Conneaut—age-group I; trap-net samples from Lorain and Sandusky—age-groups I and II; gill-net sampes from Sandusky—age-groups I, II, III, and IV). Although direct-proportion calculations of the length of whitefish based on diameter measurements of the scales have been

demonstrated to be generally satisfactory (Van Oosten, 1923) the younger age groups tend, nevertheless, to have higher calculated lengths for the earlier years of life than do older fish. It is possible that the earlier calculated lengths of the Erie whitefish (age-groups I and II included in the computations) and of the Conneaut whitefish (age-group II, but not age-group I, included) may have been increased somewhat by the inclusion of younger fish than were employed in the calculations for the Lorain and Sandusky whitefish.

It should be mentioned finally that the numbers of specimens were so small at the higher ages that the presence of only a few individuals of exceptionally slow or rapid growth would have a profound effect on the determination of calculated lengths in the later years of life.

It is of some value to know to what extent the elimination or reduction of the effects of certain of the disturbing factors just listed might bring about an improvement in the agreement of the calculated lengths of whitefish from different localities. Two illustrations will be given that throw light on this question.

Comparisons of certain data for the whitefish from Sandusky and Lorain bring out clearly the effects of annual fluctuations in growth rate in conjunction with differences in the calendar years in which collections were made off the two ports (Sandusky—1927, 1928, and 1929; Lorain—1929 and 1930). It was suggested earlier that because of differences in the years of collection the data for the whitefish from Lorain were affected more severely than were those for the Sandusky whitefish by the poor conditions for growth in 1929 and 1930 and hence that the variations in the rate of growth in different calendar years might account for the lower average sizes of the age groups in the Lorain collections. This opinion is supported fully by the data of Table 19.

Although the average sizes of the Lorain whitefish tended to be smaller than those of Sandusky fish of the same age (Tables 16 and 17), and the grand average calculated lengths of the Lorain specimens beyond the second

TABLE 19.—*Comparison of calculated total lengths (inches) of certain age groups of the Sandusky and Lorain collections*

[To illustrate the effects of annual fluctuations in growth rate. See text for explanation. Asterisks designate length at capture.]

Age group	Sex	Year class	Year of capture	Port	Number of fish	Calculated length at end of year of life				
						1	2	3	4	5
III	Male	1926	1929	Sandusky	421	6.9	12.9	16.3	17.5*	....
	do.	do.	do.	Lorain	165	6.9	12.7	15.9	17.2*	....
	do.	1927	1930	do.	58	7.5	12.8	15.8	16.9*	....
III	Female	1926	1929	Sandusky	88	7.1	13.4	16.8	18.2*	....
	do.	do.	do.	Lorain	8	6.9	13.5	17.0	18.4*	....
	do.	1927	1930	do.	9	7.2	12.7	15.9	17.1*	....
IV	Female	1925	1929	Sandusky	40	7.0	12.6	16.1	18.1	19.0*
	do.	do.	do.	Lorain	11	7.1	12.7	16.1	18.4	19.3*
	do.	1926	1930	do.	69	7.1	12.8	16.2	17.8	18.5*

year of life were distinctly less than those of Sandusky whitefish (Table 18), comparisons of the calculated growth of members of the same age group captured in the same year (1929) fail to reveal an advantage for the fish of either port (Table 19). It is true that in 1929 the III-group males from Sandusky were longer than the III-group males from Lorain at the end of the second and third years of life and at capture near the end of the fourth year. On the other hand, both the III-group and IV-group females of the 1929 collection from Lorain were with only two exceptions (first year of life of the III-group; third year of life of the IV-group) longer at corresponding ages than females from the 1929 Sandusky collection. The last calculated length and the length at capture of Lorain whitefish taken in 1930 were consistently lower, however, than the corresponding lengths of fish of the 1929 collection from the same port. This relationship can be attributed to the poor growth in 1929 and especially in 1930.

It is reasonable to hold, therefore, that annual fluctuations in growth rate, together with differences in the years of collection, were largely responsible for the observed variations in the general growth of whitefish taken off the ports of Sandusky and Lorain. Aside from the differences in the years of capture the two collections were closely comparable since both were taken during the spawning period and all fish younger than the V group were captured by the same gear—trap nets. (The V-group and older fish of the Sandusky gill-net collections were employed in the study of growth; at these higher ages, however, no differences were found between the average lengths of whitefish of the same age taken by gill nets and trap nets.)

Growth curves based exclusively on the older age groups provide a second device for the reduction or elimination of certain selective and other distorting factors. The omission of all age groups younger than the V group in the preparation of Table 20 has made possible: the elimination of the effects of selection on the basis of maturity (all Lake Erie whitefish almost certainly are mature by the sixth year of life—see p. 245); the reduction or possible elimination of selection by gear, particularly as it affected the younger whitefish taken in large-mesh gill nets off Erie (see last sentence of preceding paragraph concerning gill-net samples from Sandusky); the reduction of the effects of Lee's phenomenon.

The data of Table 20 were probably affected, however, by annual fluctuations in growth rate.[19] Differences from port to port in the earlier selective destruction of the rapidly growing individuals in the fishery also may have influenced the data. The individuals that reached legal size first undoubtedly were subjected to greater destruction than were the slowly growing members of the same year classes. The extent of this selective destruction doubtless varied with local differences that may have existed in the intensity of the fishery.

[19] The exclusion of age-groups III and IV of the Sandusky and Lorain collections did much to reduce differences traceable to the sharp decline in growth rate in 1929 and 1930. These younger fish, which were still in the period of rapid growth, were affected more severely by the decrease in growth rate than were the slowly growing members of the older age groups.

TABLE 20.—*Calculated total lengths (inches) of whitefish captured off different ports with all age groups younger than the V group excluded*

[Numbers of fish in parentheses]

Port	Year of life										
	1	2	3	4	5	6	7	8	9	10	11
Sandusky, O.	6.7 (282)	12.4 (282)	15.7 (282)	17.8 (282)	19.3 (282)	20.3 (108)	21.0 (60)	21.7 (54)	22.4 (50)	22.8 (44)	23.3 (27)
Lorain, O.	6.9 (32)	12.7 (32)	16.2 (32)	18.2 (32)	19.4 (32)	20.3 (12)	20.9 (5)	21.7 (3)	22.3 (3)	22.8 (2)	23.1 (1)
Conneaut, O.	6.4 (9)	11.8 (9)	15.0 (9)	17.7 (9)	19.2 (9)	20.3 (7)	20.9 (5)	21.7 (4)	22.3 (3)	22.8 (3)	23.1 (2)
Erie, Pa.	6.5 (40)	12.0 (40)	15.8 (40)	18.1 (40)	19.8 (40)	20.9 (31)	21.8 (21)	22.6 (18)	23.1 (16)	23.7 (14)	24.2 (12)

Although the averages based on the V-group and older fish cannot be considered entirely free from the effects of all distorting factors, the reduction or elimination of certain of them through the exclusion of the data for the younger age groups did bring about a substantial improvement in the agreement of the calculated lengths of whitefish from different localities. Comparisons of Tables 18 and 20 reveal that, aside from the low calculated lengths of Conneaut fish in the first three years of life, the differences between growth of the Sandusky whitefish and the whitefish from Lorain and Conneaut were for practical purposes eliminated by the omission of the younger age groups. In the fifth and later years especially the agreement among the three collections was remarkably close (maximum discrepancy of 0.2 inch). The calculated lengths of the Erie fish were low in the first and second years. The advantage of the Erie whitefish beyond the second or third year, however, remained practically the same with respect to the Sandusky whitefish, but was reduced markedly with respect to fish from Lorain and Conneaut.

It appears, then, that each refinement that eliminates or reduces the effects of factors that might produce "apparent" differences in the growth of whitefish from the various localities brings about an improvement in the agreement of the curves of general growth.

Because of the considerations just outlined the calculated lengths of Table 18 cannot be accepted as proof of the existence of correspondingly large real differences in the growth rate of whitefish from different regions of Lake Erie. It is true that some local differences in growth rate may exist; however, the data at present available are inadequate conclusively to demonstrate their presence, much less measure their true extent. Consequently the combination of the data for all ports for the determination of a "general" growth curve seems to be desirable. These combined data may be found at the bottom of Table 18 and are depicted graphically in Figure 3.

The Lake Erie whitefish made their greatest growth in length in the first year of life (6.9 inches; 147 millimeters). Growth was fairly rapid in the

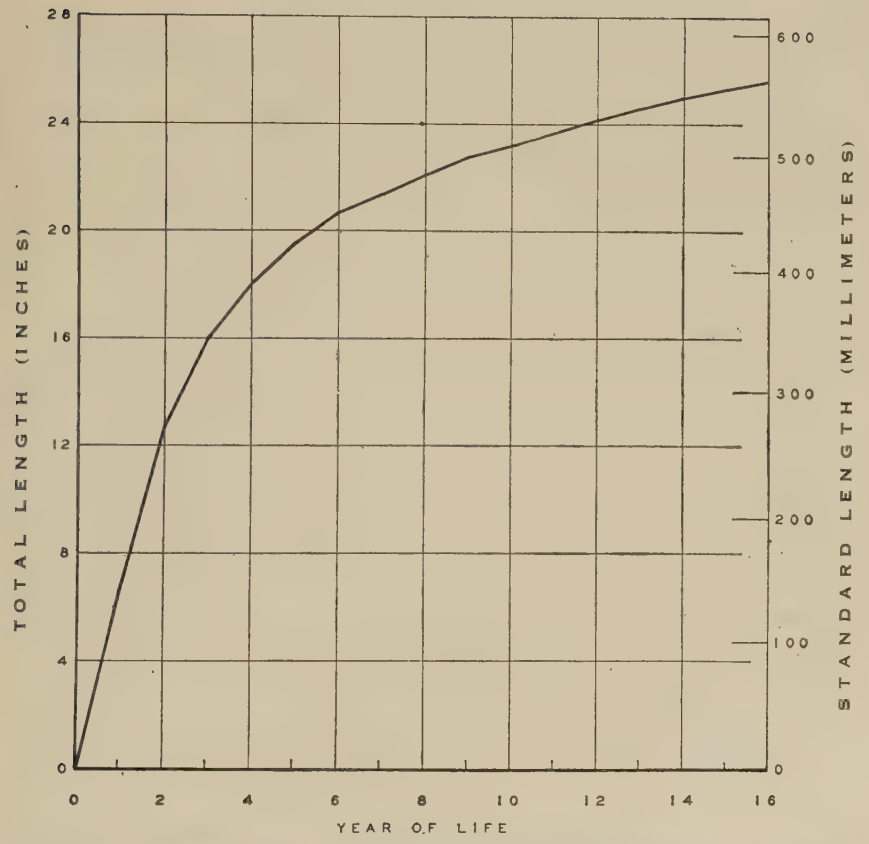

FIGURE 3.—Calculated growth in length of the Lake Erie whitefish (sexes combined) as determined from the combination of data for all localities.

second year also (5.8 inches; 124 millimeters). The annual increments of length decreased rather consistently beyond the first year.[20] Growth was relatively slow in the later years. The increase was less than 1.0 inch (equivalent to about 22 millimeters of standard length) in every year of life later than the sixth. Beyond the eleventh the increments varied from 0.3 to 0.5 inch (10 millimeters or less).

The calculated lengths at the end of the third and fourth years of life confirm the earlier statement that the Lake Erie whitefish normally reaches 16.9 inches (365 millimeters), the length equivalent to the minimum legal

[20] Some apparent inconsistencies between the increments of standard length and total length can be traced to the changes at certain standard lengths in the factors employed for conversions to total length—see Table 15. The rounding of total lengths to the nearest 0.1 inch also contributed to the discrepancies.

weight of 1¾ pounds, during the fourth year of life. With average growth, Lake Erie whitefish must survive more than 5 years to attain the length of 20 inches and more than 11 years to exceed the length of 2 feet.

Growth in weight.—The weights of Table 21, which were computed by means of the general length-weight equation given on p. 231 correspond exactly with the lengths of Table 18. By reason of the nature of the length-weight relationship (increase of weight to the 3.1523 power of the length) the differences between the calculated weights of whitefish of different sex or from different ports were relatively greater than the corresponding discrepancies in calculated lengths.

The advantage of the female whitefish over the males with respect to calculated weight tended to increase rapidly during the early years of life. In the Erie collections the sex difference rose from 0.01 pound at the end of the first year of life to 0.15 pound at the end of the fourth (no data for later years). For the Lorain collections this difference increased steadily from 0.01 pound at the end of the first year of life to a maximum of 0.28 pound at the end of the fifth. Beyond the fifth year of life the sex differences in calculated weight varied irregularly; the average advantage of the females was 0.18 pound in the sixth to ninth years, inclusive. The calculated weights of Sandusky males and females differed 0.01 pound at the end of the first year (with the females the heavier) and were the same at the end of the second. In the later years, however, the advantage of the females increased from 0.06 pound at the end of the third year to 0.30 pound at the end of the eighth (equal differences in the fifth and sixth years); the differences in the later years ranged between 0.25 pound in the tenth year and 0.36 pound (the maximum difference) in the eleventh.

The weight advantage of the females of the collections of all ports combined rose from 0.01 pound at the end of the first year of life to 0.36 pound at the end of the eighth year and subsequently varied between 0.32 pound in the ninth year and 0.42 pound (the maximum difference) in the eleventh. With growth in weight as with growth in length the existence of selective factors that may have contributed to certain of the observed sex differences should be kept in mind.

The calculated weights (sexes combined) reveal fairly wide differences in the growth of whitefish captured off different ports. The weights of the Erie specimens differed little from those of whitefish from Lorain and Sandusky at the end of the first and second years of life but were somewhat greater than the weights of the Conneaut fish. In the third and later years, however, the Erie whitefish were distinctly heavier than fish of corresponding age in the remaining collections. The minimum advantage of the Erie specimens (the advantage over the Sandusky fish) increased from 0.10 pound at the end of the third year of life to 1.00 pound at the end of the thirteenth (irregularity in the trend in the ninth year) and was 0.99 pound at the end of the fourteenth year of life. The Erie whitefish were thus a pound heavier than the Sandusky fish in both of the last two years of life for which comparisons are possible. Even greater was the

TABLE 21.—*Calculated weight (pounds) of the Lake Erie whitefish according to sex and port*

[In the bottom section annual increments of weight have been included. The weights in this table correspond to the lengths of Table 18 and were computed by means of the general length-weight equation]

Port	Sex	Calculated weight at end of year of life															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sandusky, O.	Male	0.09	0.69	1.43	2.12	2.72	3.25	3.71	4.10	4.61	5.00	5.25	5.61	..	..	..	..
	Female	0.10	0.69	1.49	2.30	2.98	3.51	3.99	4.40	4.87	5.25	5.61	5.91	6.20	6.53	..	..
	Both	0.10	0.69	1.45	2.21	2.83	3.34	3.81	4.21	4.66	5.06	5.41	5.71	5.98	6.31	..	..
Lorain, O.	Male	0.10	0.68	1.37	1.96	2.39	2.81	3.20	3.58	3.99	4.26	4.57	..	..	..	..	..
	Female	0.11	0.73	1.51	2.16	2.67	3.02	3.39	3.83	4.07	..	..	..	..	..	..	..
	Both	0.10	0.69	1.40	2.02	2,49	2.87	3.27	3.66	4.02	4.29	4.61	..	..	..	..	..
Conneaut, O.	Both	0.08	0.56	1.23	1.88	2.45	2.94	3.29	3.71	4.04	4.37	4.69	5.06	5.25	..	..	..
Erie, Pa.	Male	0.10	0.70	1.49	2.36	..	..	..	..	..	..	..	..	..	..	..	..
	Female	0.11	0.73	1.63	2.51	3.32	3.94	4.32	..	..	..	..	..	..	..	..	..
	Both	0.10	0.71	1.55	2.36	3.09	3.76	4.29	4.81	5.25	5.67	6.09	6.49	6.98	7.30	7.54	7.83
All ports	Male	0.10	0.69	1.41	2.07	2.65	3.16	3.61	3.99	4.49	4.84	5.12	5.47	..	..	..	..
		0.10	0.59	0.72	0.66	0.58	0.51	0.45	0.38	0.50	0.35	0.28	0.35	..	..	..	..
	Female	0.11	0.71	1.52	2.28	2.94	3.46	3.94	4.35	4.81	5.18	5.54	5.84	6.12	6.45	..	..
		0.11	0.60	0.81	0.76	0.66	0.52	0.48	0.41	0.46	0.37	0.36	0.30	0.28	0.33	..	..
	Both	0.10	0.69	1.45	2.18	2.79	3.32	3.78	4.21	4.63	5.03	5.38	5.71	6.05	6.38	6.60	6.87
		0.10	0.59	0.76	0.73	0.61	0.53	0.46	0.43	0.42	0.40	0.35	0.33	0.34	0.33	0.22	0.27
	Both[1]	0.04	0.31	0.66	0.99	1.26	1.50	1.72	1.91	2.10	2.28	2.44	2.59	2.75	2.89	2.99	3.11
		0.04	0.27	0.35	0.33	0.27	0.24	0.22	0.19	0.19	0.18	0.16	0.15	0.16	0.14	0.10	0.12

[1] Weights and increments of weight in kilograms

advantage of the Erie whitefish over those from Conneaut and Lorain. For example, Conneaut whitefish at the end of the thirteenth year of life had the same weight as Erie whitefish that were 4 years younger, and Lorain whitefish at the end of the eleventh year of life weighed less than Erie fish at the end of the eighth.

In weight as in length the growth of the whitefish of the Sandusky collections may be termed intermediate. The advantages of Sandusky whitefish over those from Conneaut and Lorain in the third and later years of life were much the same as the advantages of the Erie whitefish over the fish from Sandusky. The greatest difference occurred at the end of the thirteenth year when Sandusky specimens were 0.73 pound heavier than fish of the same age from Conneaut.

It may be repeated here that significant differences did exist in the

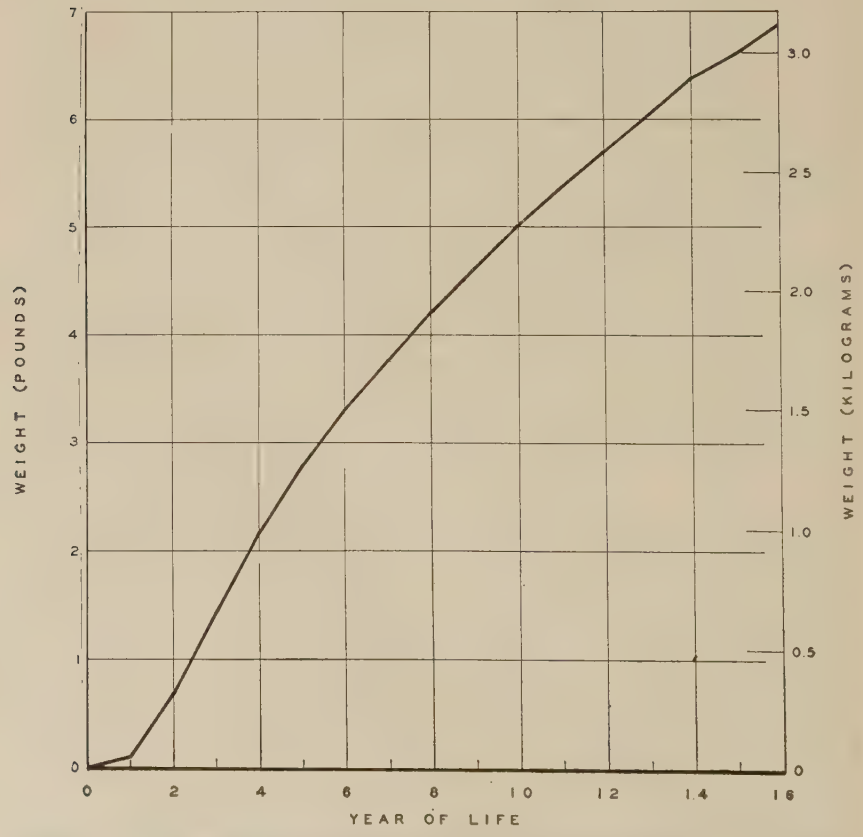

FIGURE 4.—Calculated growth in weight of the Lake Erie whitefish (sexes combined) as determined from the combination of data for all localities.

growth of whitefish in the collections from the various ports, but that the presence of certain disturbing factors outlined in preceding sections renders unsafe the conclusion that permanent significant differences in growth rate characterize also the stocks from which the samples were taken.

The data on growth in weight of the whitefish of the combined collections (bottom of Table 21 and Fig. 4) show that the greatest increase of weight occurred in the third year of life (0.76 pound; 0.35 kilogram). The increment was large in the fourth year also (0.73 pound; 0.33 kilogram) and exceeded a half pound (0.23 kilogram) in the second, fifth, and sixth years. Although the annual increments of weight exhibited a general downward trend beyond the third year of life, they remained substantial nevertheless even at advanced ages. In only one year of life (the fifteenth) did the increment fall below a quarter pound. These relatively large increases of weight in the later years are in contrast with the small increases of length in corresponding years (Table 18).

The Lake Erie whitefish attained the minimum legal weight of 1¾ pounds during the fourth year—probably near the middle of the fourth growing season. The weight of 2 pounds was reached toward the close of the same year of life. The approximate ages at which certain other weights were reached were: 3 pounds—middle of the sixth year; 4 pounds—middle of the eighth year; 5 pounds—near the end of the tenth year; 6 pounds—late in the thirteenth year.

Annual Fluctuations in Growth Rate

Tabulations of the calculated growth histories of the best represented age groups of whitefish taken off Sandusky (Table 22) and Lorain (Table 23) permit comparisons of increments of growth in corresponding years of life but in different calendar years. In order to eliminate the distorting effects of sex differences in growth rate and of Lee's phenomenon, the data were recorded separately for fish of each sex in each age group. The arrangement of the tables is such that the columns show the growth increments of whitefish in the same calendar year but in different years of life, and the horizontal rows the increments for fish in the same year of life but in different calendar years. Each descending diagonal row gives the growth history of an individual age group. The calendar year in which the first year of growth occurred identifies the year class to which each age group belonged.[21]

The general trends in the annual fluctuations in growth rate can be determined by the examination of the increments of Tables 22 and 23. For example, the two available comparisons of growth in 1924 and 1925 showed both a decline (III-group males) and an improvement (IV-group

[21] Similar tabulations made for whitefish from Erie Pennsylvania, failed to reveal a trend in the annual fluctuations in growth. This lack of consistency may be attributed to the relatively small numbers of fish for which records of sex were available and to the distorting effects of the selection by the three types of gear (p. 184) employed. Collections of whitefish were made off Conneaut, Ohio, in only one year.

TABLE 22.—*Comparison (based on collections taken off Sandusky, Ohio, 1927–1929) of growth increments (millimeters of standard length) of whitefish of the same sex and age and in the same year of life but in different calendar years*

[Fish taken earlier than November were excluded. Asterisks designate increments at year of capture]

Age group and sex	Year of life	Calendar year					
		1924	1925	1926	1927	1928	1929
III (Male)	1	145	135	148	...	...	...
	2	...	113	121	129	...	...
	3	...	...	73	76	71	...
	4	...	...	...	41*	38*	30*
III (Female)	1	...	145	152	...	...	...
	2	...	...	128	134	...	...
	3	...	...	...	82	77	...
	4	...	...	...	...	33*	30*
IV (Female)	1	135	150	...	...	...	...
	2	...	114	120	...	...	...
	3	...	...	77	74	...	...
	4	...	...	...	57	48	...
	5	...	...	...	...	25*	18*

TABLE 23.—*Comparison (based on collections taken off Lorain, Ohio, in 1929 and 1930) of growth increments (millimeters of standard length) of whitefish of the same sex and age and in the same year of life but in different calendar years*

[All fish taken in November and December. Asterisks designate increments of year of capture]

Age group and sex	Year of life	Calendar year					
		1925	1926	1927	1928	1929	1930
III (Male)	1	...	147	160	...	...	...
	2	...	...	125	115	...	...
	3	...	...	...	69	64	...
	4	...	...	...	...	31*	27*
IV (Male)	1	136	146	...	...	...	...
	2	...	119	123	...	...	...
	3	...	...	75	63	...	...
	4	...	...	...	47	37	...
	5	...	...	...	...	21*	19*
III (Female)	1	...	148	154	...	...	...
	2	...	...	142	119	...	...
	3	...	...	...	77	68	...
	4	...	...	...	...	30*	28*
IV (Female)	1	151	153	...	...	...	...
	2	...	121	122	...	...	...
	3	...	...	73	71	...	...
	4	...	...	...	53	39	...
	5	...	...	...	...	18*	15*

females) in growth in the latter year. Because of this disagreement no conclusion can be reached concerning the change in growth rate in 1925, although the fact that the improvement in the first-year growth of the IV-group females exceeded by 5 millimeters the decline in the growth of the III-group males does indicate a possible slight increase in growth rate in 1925. On the other hand, all 6 comparisons of growth (both ports) in 1925 and 1926 indicated better growth in the latter year, and 7 of 8 comparisons showed better growth in 1927 than in 1926. The growth rate

appears to have reached a peak in 1927, for without a single exception the increments for the later years indicated a progressive decline in growth rate in 1928, 1929, and 1930. It should be noted that the trends in the growth of whitefish from Sandusky and Lorain agreed closely.

Although the description of fluctuations in growth rate given in the preceding paragraph is fully valid, a more exact estimate of the changes that occurred seems to be desirable. Accordingly, computations were made of the percentage changes in growth rate from year to year.[22] These percentage fluctuations in growth rate are listed separately (for each sex and for the sexes combined) for collections from Sandusky and Lorain in Table 24. Each percentage represents the deviation of the growth from the average for 1925–1929, the years for which data were available for whitefish from both ports. At the bottom of the table the percentages for the two localities have been combined to show the general deviation from the 1924–1930 mean.

The trends in the percentage deviations of the growth of males and females from the average were closely similar in both the Sandusky and Lorain collections although differences of more than 5.0 percent did occur in several years (Sandusky—1924, 1925, and 1928; Lorain—1925, 1929, and 1930). Because of these similar trends a combination of the percentages (unweighted mean) for the sexes from each locality seems to be valid.

TABLE 24.—*Percentage deviation of each year's growth of the Lake Erie whitefish taken off Sandusky, Ohio, and Lorain, Ohio, from the mean growth in 1925–1929*

[Below, the percentages for whitefish from both ports were combined to show the fluctuations about 1924–1930 mean]

Port	Sex	Percentage deviation in year						
		1924	1925	1926	1927	1928	1929	1930
Sandusky, O.	Male	4.9	−2.2	5.9	11.4	4.3	−19.2	.....
	Female	−7.3	3.2	8.1	9.6	−1.0	−19.9	.....
	Both	−1.2	0.5	7.0	10.5	1.6	−19.6	.....
Lorain, O.	Male	.....	−2.0	5.1	11.3	−0.3	−14.1	−26.3
	Female	.....	6.2	7.5	10.1	−2.2	−21.6	−32.6
	Both	.....	2.1	6.3	10.7	−1.2	−17.8	−29.4
Sandusky and Lorain	Both	3.2	5.7	11.0	15.0	4.6	−14.3	−25.0

The comparison of the percentages for the whitefish from the two ports (sexes combined) reveals a remarkably good agreement. The maximum discrepancy was 2.8 percent (1928) and the average difference for 1925–1929 was only 1.4 percent. This agreement justifies the combination of the data from the two localities to provide a general estimate (bottom of Table 24) of the annual percentage fluctuations in the growth of the Lake Erie whitefish from these ports over the 7-year period 1924–1930 (see also

[22] The procedure was outlined by Hile (1941) and consequently need not be described here.

Fig. 5). The combined percentages show the growth of the Lake Erie whitefish from Sandusky and Lorain to have been slightly above (3.2 percent) the 1924–1930 average in 1924. Growth improved during the next three years, reaching a peak of 15.0 percent above average in 1927. A rapid decline beginning in 1928 carried the growth rate to the level of 25.0 percent below average in 1930. The nature of the curve in Figure 5 is suggestive of a cyclic fluctuation in growth rate.

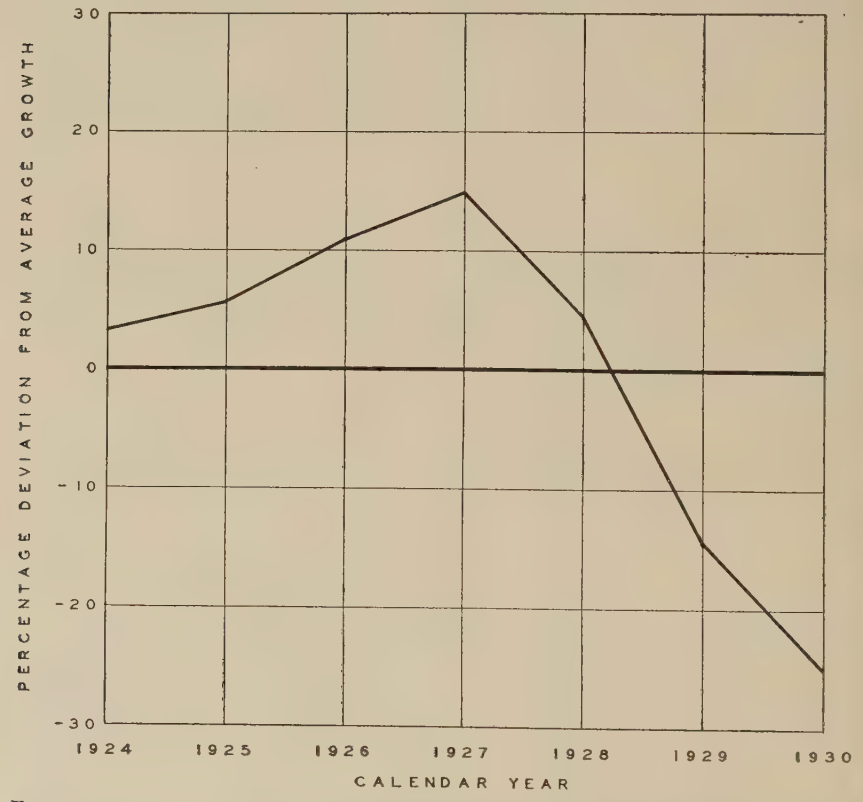

FIGURE 5.—Annual fluctuations of the growth rate (in length) of Lake Erie whitefish as determined from the best represented age groups of the Sandusky and Lorain collections and expressed as percentage deviations from the 1924–1930 mean.

The close agreement between the annual fluctuations in the growth of whitefish taken off Sandusky and Lorain suggests two possibilities: first, that the whitefish that spawn at these two localities occupy the same grounds during the growing season; or second, that conditions which control the growth of the Lake Erie whitefish are similar in the different areas of the lake inhabited by the two stocks.

In an attempt to determine probable causes of the observed annual fluctuations in growth rate, consideration was given to the possible effects of changes in population density and of annual variations in certain limnological and meteorological conditions.

The density of the whitefish population does not appear to have had any effect on the rate of growth. Although the 1926 year class of whitefish (and of at least six other species) was exceptionally strong, the growth in 1926 was distinctly superior to growth in 1925. It is particularly significant that in spite of the phenomenal abundance of young fish of so many species, the first-year growth of whitefish of both sexes was more rapid in 1926 than in 1925. Furthermore, the growth of whitefish improved again in 1927 and did not decline until 1928–1930, in which years the combined effects of natural mortality and destruction of the 1926 year class in the commercial fishery must have been bringing about a reduction in the density of the population.

Meteorological-limnological factors considered were: mean wind velocity; percentage of possible sunshine; precipitation; turbidity of the water; and water temperatures. Conditions at Erie, Pennsylvania, were held to be most pertinent, since according to our best information, that port is near the center of the eastern area occupied by the whitefish during the summer. Data on the aforenamed factors [23] were tabulated and examined for the six months, May through October, which period is believed to include all possible months in which any significant amount of the growth of the whitefish could have taken place. The basis for this belief is given briefly in the following paragraphs.

Unfortunately the available data were unsuited for an exact study of the course of the season's growth of the Lake Erie whitefish. The Sandusky and Lorain collections were made in the late fall during or shortly before the spawning period and hence at a time when most or all of the current year's growth must have been completed. The earliest collection was made July 9–12, 1929, at Conneaut, but there are no other samples from this port for comparison, and data on sex were lacking (the sexes do not grow at identical rates—see preceding sections). At Erie, collections were made as early as late July and as late as early December, but here the obviously severe distorting effects of gear selection (p. 184) together with the scanty information on sex again made precise analysis unfeasible.

Certain general statements concerning the course of the season's growth can be made nevertheless. With the Conneaut samples, for example, the estimate that a fourth to a third of the 1929 growth had been completed by July 9–12 is probably near the truth. At Erie the available data on the

[23] Information on wind velocity, percentage of possible sunshine, and precipitation was obtained from the U. S. Weather Bureau's publication, "Climatological Data for the United States by Sections," and data on the turbidity and temperature of the water were obtained from the Annual Reports of the Commissioners of Water Works in the City of Erie, Pennsylvania. Records of turbidity and temperature describe conditions at the intake for the Chestnut Street Plant, located in the open lake, 5,100 feet north of Presque Isle Peninsula. The crib of this intake is covered by 22 feet of water at low water level.

earlier months (based principally on the 1929 collections) indicated active growth in late July, August, and at least part of September. The information for later months was conflicting. In 1928, the increments of the current year for age-group II (the only age group with reasonably adequate representation in more than one month) indicated substantially more growth for fish captured in October than for those taken in September. Furthermore, additional successive small increases in the increment for whitefish collected in November and early December suggest the possibility of a limited amount of growth in the late fall. In 1929 also, members of the II group captured in October had completed more growth than had fish of the same age taken in the preceding month. In age-group III, however, estimates of growth completed by fish captured in September and October were the same, and in the IV group the increment through October was slightly the smaller.

The conflicting results described in the latter part of the preceding paragraph prevent the drawing of a definite conclusion as to the time the season's growth ends. Possibly the course of growth varies with calendar year and also with age and sex. (See Hile, 1941, for examples of differences in the growing season related to sex and age.) At any rate, it seems valid to hold that if any growth occurs later than October, the amount is unimportant.

Information on the time at which the growth of the Lake Erie whitefish begins is even less satisfactory than that on the time at which it ends. The fact that fish captured off Conneaut had, as stated earlier, completed from a fourth to a third of their 1929 growth by July 9–12 makes it safe to conclude that active growth was taking place during at least part of June. Whether or not these whitefish were growing throughout that month or even during part of May would be determined by the rate of the early-season growth. On that point we have no data. Some growth in May must be held a possibility; growth earlier than that month, however, appears altogether unlikely.

The general conclusion that the growth of the Lake Erie whitefish does not begin before May or continue to any significant extent beyond October (the true length of the growing season, of course, may be substantially less than the indicated 6 months) is entirely consistent with the available published information on the growing season of fish in the same general latitude (Hile, 1936 and 1941; Beckman, 1943; Deason and Hile, 1947).

Only rarely did Beckman find evidence for growth of game fishes in the inland waters of the southern third of the Lower Peninsula of Michigan before May, and he set the average time at which annulus formation is completed in the region as the middle of the month. In more northerly regions annulus formation is completed later—in the first part of June in the upper two-thirds of the Lower Peninsula and by the end of June in the Upper Peninsula. Hile (1941) believed that the growth of the rock bass (*Ambloplites rupestris*) in northeastern Wisconsin ordinarily begins in

June but emphasized that the current year's annulus may not be visible on the scales of older fish as late as early July. Deason and Hile (1947) estimated that the growth of the kiyi (*Leucichthys kiyi*) of northern Lake Michigan begins in May.

The time at which the season's growth ends also seems to vary widely, but evidence is lacking for significant growth after October. In four populations of ciscoes (*Leucichthys artedi*) from neighboring lakes in northeastern Wisconsin the date of cessation of growth ranged from as early as the end of July to as late as the end of September or early October (Hile, 1936). Rock bass from the same region had completed roughly 75 percent of the year's growth at capture in late July and early August, and Beckman (1943) gave similar figures for bluegills (*Lepomis machrochirus*) and pumpkinseeds (*L. gibbosus*) from southeastern Michigan. The data of Deason and Hile (1947) suggested some local variation in the time at which the growth of the kiyi ends, but yielded no indication of growth later than September.

Of the five limnological-meteorological factors considered, two—wind velocity and percentage of possible sunshine—gave not the slightest indication of correlation with the annual fluctuations in the growth of the Lake Erie whitefish over the period, 1924–1930.

Water temperatures at Erie tended to be high in certain months and combinations of months in years when the growth of whitefish was below average and low in years when growth was above average. None, however, of the several coefficients of correlation computed was significant.[24] The highest value determined for any single month was $r = -0.607$ for growth and water temperatures in July. The highest coefficient for a combination of months was $r = -0.612$ for growth and water temperatures in July and August. The correlation was nearly as great ($r = -0.607$) with the combination June, July, and August.

Significant correlations were determined between growth and precipitation and between growth and the turbidity of the lake water at Erie (Table 25). At first thought these correlations might be taken as strong evidence that the amount of growth in a particular year is influenced greatly by rainfall and turbidity, with heavy precipitation in July and August (especially in July) and low turbidity in the early season (particularly May and June) and in October exerting beneficial effects. The examination of the original records revealed, however, that within the 7-year period under investigation turbidities and amounts of precipitation frequently tended themselves to be correlated. This situation complicates in no small measure the interpretation of the data.

As an illustration, the coefficient of correlation between precipitation in July and August and turbidity in May, June, and October was determined to be -0.905, a value well beyond the level ordinarily considered highly

[24] With seven pairs of variables r becomes "significant" ($p = 0.05$) at the absolute value 0.754 and "highly significant" ($p = 0.01$) at 0.874.

TABLE 25.—*Correlations between the annual fluctuations in precipitation or in the turbidity of lake water at Erie, Pennsylvania, and the growth of the Lake Erie whitefish, 1924–1930*
[In this tabulation an absolute value of $r = 0.754$ is "significant" ($p = 0.05$) and one of 0.874 is "highly significant" ($p = 0.01$)]

Environmental factor	Month or months	r
Precipitation	July	0.833
	July and August	0.855
Turbidity	May	−0.790
	June	−0.776
	May, June, and October	−0.810
	May and June	−0.790
	May, June, and July	−0.768

significant. For the want of a credible explanation for a physical connection between rainfall and turbidity in these two combinations of months, this high correlation is viewed as nothing more than a regrettable statistical accident, but accident or not, it still throws grave doubt on the real meaning of the "significant" coefficients, 0.855 and −0.810, the highest computed for any groupings of months. If growth is in fact correlated positively with July–August precipitation, it must inevitably exhibit a certain degree of "apparent" negative correlation with turbidity in May, June, and October. Conversely, a "true" negative correlation between growth and turbidity in these three months will tend to be accompanied by an "apparent" positive correlation with rainfall in July and August. Thus, it is impossible to establish a correlation between growth and either one of the environmental factors independent of the other. This fact is brought out forcibly by the computation of partial coefficients of correlation. If July-August precipitation is held constant, the coefficient of correlation between growth and turbidity in May, June, and October is only −0.163. When turbidity in those months is held constant, the correlation between growth and rainfall in July and August is but 0.490. Both partial coefficients are far from significant (for these partial coefficients the absolute value of r corresponding to $p = 0.05$ is 0.811).

The situation is similar with the highest correlations computed between growth and conditions in any individual month ($r = 0.833$ for growth and precipitation in July; $r = -0.790$ for growth and turbidity in May). Here again the correlation between the environmental factors ($r = -0.641$) is sufficiently high to throw in doubt the significance of the correlation of growth with either of them individually.

In an attempt to circumvent the difficulties imposed by the observed correlations between rainfall and turbidities, multiple coefficients were computed to determine the correlation between growth and the two factors combined. For turbidity in May, June, and October and precipitation in July and August these calculations yielded a value of $R = 0.863$ which is slightly below the significant value, $R = 0.881$. The multiple coefficient was significant ($R = 0.898$), however, when the environmental factors were turbidity in May and precipitation in July.

It may be stated in summary that the available data provide evidence for a correlation between annual fluctuations in growth rate and conditions with respect to turbidity and/or precipitation in certain months or periods of months. The relative importance of the two environmental factors cannot be assessed.

Comparison of the Growth of Whitefish in Lakes Huron, Erie, and Ontario

Earlier studies of whitefish captured in Lake Huron off Alpena, Michigan, (Van Oosten, 1939) and at four localities in Lake Ontario (Hart, 1931) make possible a comparison of the growth of the species in three of the Great Lakes (Table 26). The data for Lakes Huron and Erie are directly comparable in that they represent the calculated lengths and weights at the end of the stated years of life. The lengths and weights of the Lake Ontario whitefish, however, are the empirically determined averages for fish collected during the indicated year. Since the Ontario specimens had not completed the current season's growth [25] the lengths and weights of Table 26 are too low in comparison with the corresponding figures for whitefish from Lakes Huron and Erie. The prejudice to the Lake Ontario data from this source should be most severe at the lower ages when the annual increments of growth are relatively large and much less at the higher ages when the increments are small.

Comparisons of the calculated lengths of whitefish from Lake Huron and Lake Erie reveal that fish of the former lake had the poorer growth in the early years of life and the better in later years. The advantage of the Lake Erie fish increased from 1.9 inches at the end of the first year to the maximum of 3.8 inches at the end of the second and third years, beyond which point the advantage declined. At the end of the sixth and later years the Lake Huron whitefish were the longer, with the difference increasing regularly from 0.7 inch at the end of 6 years to 2.4 inches at the end of 12. The annual increments of length provide a ready explanation for the changes just described. These increments were much the larger for the Lake Erie whitefish in the first and second years, were equal in the third, and were without exception the greater for the Lake Huron whitefish in the fourth and later years.

Data on the calculated weights of Lake Huron whitefish are available only from the fifth through the ninth year of life as all other calculated lengths fell outside the range of the length-weight curve prepared by Van Oosten. At the end of the fifth year the calculated weight of Lake Erie whitefish was 0.5 pound greater than that of Lake Huron whitefish. Because of the robust form of the Lake Erie whitefish the weights were equal at 3.3 pounds at the end of 6 years despite the fact that the Lake Huron

[25] Hart gave no data on the actual time of capture in the growing season. In his graphical depictions of growth the points showing the average lengths and weights were placed approximately halfway between the ordinates for the next lower and next higher year of life.

TABLE 26.—*Comparison of the growth of whitefish in Lakes Huron, Erie, and Ontario*

[The lengths and weights of Lake Huron and Lake Erie whitefish are calculated values at the end of the stated years of life; the lengths and weights of the Lake Ontario whitefish are empirical values based on fish captured during the indicated years of life]

Year of life	Lake Huron[1]			Lake Erie			Lake Ontario[2]		
	Total length (inches)	Increment of length	Weight (pounds)	Total length (inches)	Increment of length	Weight (pounds)	Total length (inches)	Increment of length	Weight (pounds)
1	5.0	5.0	...	6.9	6.9	0.1	....	....	...
2	8.9	3.9	...	12.7	5.8	0.7	....	...	...
3	12.3	3.4	...	16.1	3.4	1.4	9.4	...	0.2
4	16.1	3.8	...	18.1	2.0	2.2	12.0	3.4	0.5
5	19.2	3.1	2.3	19.6	1.5	2.8	15.4	3.4	1.1
6	21.4	2.2	3.3	20.7	1.1	3.3	17.9	2.5	2.0
7	22.9	1.5	4.2	21.4	0.7	3.8	19.1	1.2	2.5
8	23.9	1.0	4.8	22.1	0.7	4.2	20.4	1.3	2.8
9	24.8	0.9	5.9	22.8	0.7	4.6	21.0	0.6	3.3
10	25.3	0.5	...	23.2	0.4	5.0	22.3	1.3	4.1
11	25.9	0.6	...	23.7	0.5	5.4	....	...	...
12	26.6	0.7	...	24.2	0.5	5.7	[3]25.8	...	[3]7.9

[1] Data adapted from Van Oosten (1939). The weights corresponding to the calculated lengths in the fifth to ninth years of life were estimated from the curve of the length-weight relationship

[2] Data adapted from Hart (1931). The standard lengths given by Hart were converted to total lengths by means of factors determined by Van Oosten (1939) for the Lake Huron whitefish

[3] Only one fish

fish were the longer by 0.7 inch. In the seventh, eighth, and ninth years, however, the weights of Lake Huron whitefish exceeded those of Lake Erie fish by 0.4, 0.6, and 1.3 pounds, respectively.

Even when allowance is made for the effects of capture of the Lake Ontario whitefish before the completion of the growing season, it is obvious that the growth of the species is considerably slower in that lake than in Lake Huron or Lake Erie.[26] For example, Ontario whitefish captured during the third year were 3.3 inches shorter than Lake Erie whitefish at the end of the second and only 0.5 inch longer than Lake Huron fish at the end of this same year. Similarly Ontario fish in their fourth year were 4.1 inches shorter than the Erie fish and 0.3 inch smaller than the Huron specimens at the end of three years. As comparisons of this type are continued through the higher ages the disparities increase. As an illustration, Lake Ontario fish were not as long in the ninth year as were Lake Erie whitefish at the end of the seventh or Lake Huron whitefish at the end of the sixth. The figures on weight serve further to bring out the slow growth in Lake Ontario. To give just one example, fish from that lake weighed the same in the ninth year as did Lake Erie and Lake Huron whitefish at the end of the sixth.

Length-Weight Relationship and Condition

General length-weight relationship.—The determination of the general length-weight relationship of the Lake Erie whitefish (Table 27) was based on the combination of materials regardless of locality,[27] year and season of capture, type of gear, or sex and state of maturity. The weights of whitefish at different lengths are shown graphically by the dots of Figure 6. The curve is the graph of the parabola that was fitted to the average lengths and weights at the intervals represented by more than one fish. Figure 6 has been so arranged as to permit ready conversions between standard lengths in millimeters and weights in kilograms and total lengths in inches and weights in pounds.

The equation for the curve of Figure 6 is:

$$W = 0.6650 \times 10^{-8} L^{3.1523},$$

where W = weight in kilograms,

and L = length in millimeters.

The weight of the Lake Erie whitefish increases as the 3.1523 power of the length. The coefficient of condition K as computed from the relationship,

$$K = \frac{W \times 10^8}{L^3},$$

therefore may be expected to increase as the 0.1523 power of the length. In other words, the Lake Erie whitefish tends to develop a more robust form with increase in length.

[26] In the preparation of Table 26 Hart's data for four localities were combined despite the possibility of some local variation in growth rate.

[27] Preliminary tabulations failed to reveal a difference between the length-weight relationships of whitefish of eastern and western Lake Erie.

TABLE 27.—*Length–weight relationship of the Lake Erie whitefish*

[Based on a combination of materials irrespective of time of capture, locality, gear of capture, sex, or state of maturity]

Number of fish	Total length (inches)	Weight (pounds)		Standard length (millimeters)	Weight (kilograms)	*K*
		Empirical	Calculated			
1	6.6	0.12	0.09	142	0.06	1.99
3	7.2	0.11	0.12	155	0.05	1.29
2	7.7	0.12	0.14	164	0.06	1.29
2	8.2	0.15	0.18	176	0.07	1.25
5	8.7	0.20	0.21	186	0.09	1.41
2	8.9	0.24	0.23	191	0.11	1.55
1	9.7	0.41	0.30	208	0.18	2.04
4	10.0	0.40	0.33	214	0.18	1.85
18	10.5	0.44	0.37	224	0.20	1.79
45	11.0	0.49	0.44	235	0.22	1.70
58	11.4	0.52	0.49	244	0.24	1.62
52	11.9	0.57	0.56	254	0.26	1.57
47	12.4	0.62	0.64	265	0.28	1.51
49	12.8	0.69	0.71	274	0.31	1.52
45	13.3	0.76	0.79	284	0.34	1.50
41	13.7	0.88	0.89	294	0.40	1.57
54	14.2	0.98	0.99	305	0.44	1.57
66	14.7	1.12	1.10	315	0.51	1.62
82	15.1	1.21	1.20	324	0.55	1.62
96	15.6	1.34	1.34	335	0.61	1.61
155	16.1	1.48	1.45	344	0.67	1.64
220	16.4	1.63	1.59	354	0.74	1.67
346	16.9	1.76	1.74	364	0.80	1.65
482	17.3	1.91	1.89	374	0.87	1.66
489	17.8	2.08	2.05	384	0.94	1.66
441	18.2	2.26	2.23	394	1.03	1.68
311	18.7	2.44	2.41	404	1.11	1.68
189	19.2	2.67	2.61	414	1.21	1.71
156	19.6	2.83	2.81	424	1.28	1.68
107	20.0	3.04	3.00	433	1.38	1.70
80	20.5	3.22	3.25	444	1.46	1.67
51	20.8	3.48	3.48	454	1.58	1.68
38	21.3	3.60	3.76	465	1.63	1.62
23	21.8	3.94	3.99	474	1.79	1.68
20	22.3	4.24	4.29	485	1.92	1.69
7	22.7	4.58	4.55	494	2.08	1.72
7	23.1	4.46	4.93	507	2.02	1.55
18	23.4	5.16	5.18	515	2.34	1.71
8	23.8	5.38	5.41	522	2.44	1.72
12	24.3	5.71	5.84	535	2.59	1.69
8	24.8	6.11	6.16	544	2.77	1.72
6	25.2	6.14	6.49	553	2.79	1.65
3	25.7	7.42	6.90	564	3.37	1.88
3	26.1	7.07	7.26	573	3.21	1.70
1	26.4	7.50	7.54	580	3.40	1.74
1	27.1	8.25	8.17	595	3.74	1.78
1	27.3	9.88	8.39	600	4.48	2.07
1	28.8	10.75	9.88	632	4.88	1.93

Although in general the agreement between the empirical and calculated weights was fair, the data exhibited rather large discrepancies at certain lengths. Among the largest disagreements at lengths employed in fitting the equation were those at 9.7, 10.0, 10.5, 23.1, 24.3, 25.2, 25.7, 26.1, 27.1, 27.3, and 28.8 inches. The agreement was generally poor between the calculated and empirical weights of the individual fish not used for deriving the equation. (Attention should be given to the relative as well as the actual extent of the discrepancies.) A feature of the discrepancies lay in the tendency for the disagreements to be consistently in the same direction over rather large intervals of length (all calculated weights exceeded the empirical weights at 7.2–8.7 inches, 12.4–14.2 inches, and 23.1–25.2

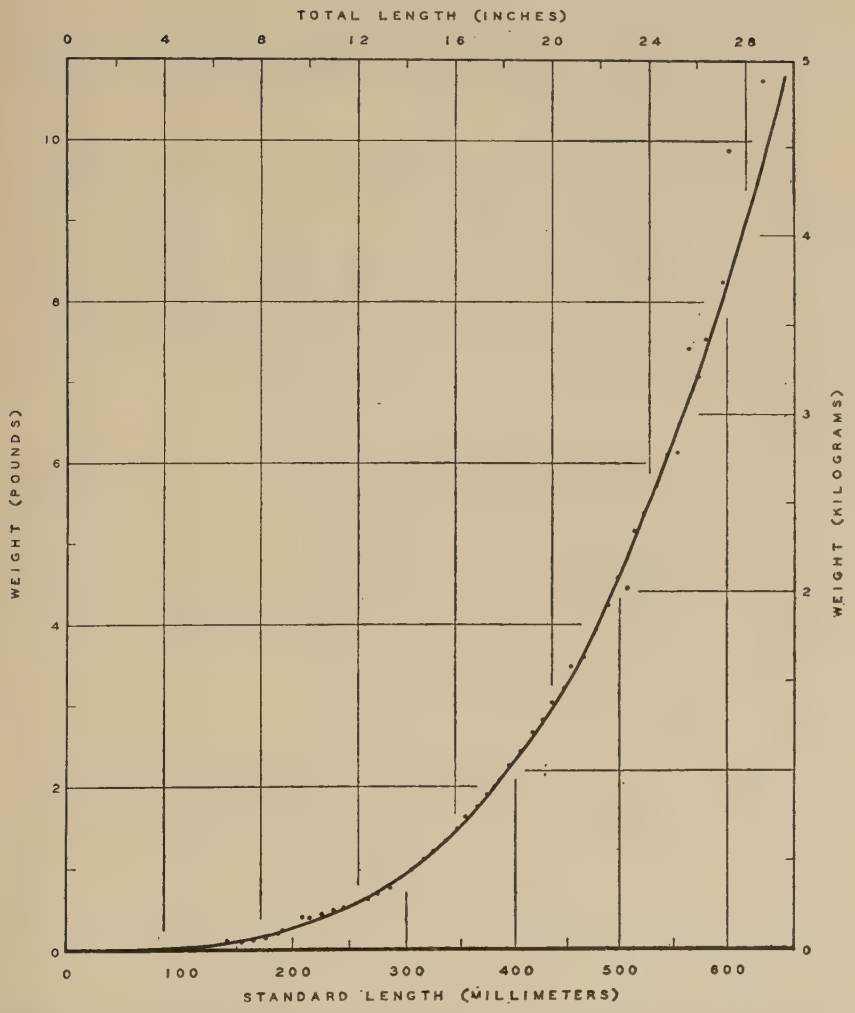

FIGURE 6.—Length-weight relationship of the Lake Erie whitefish as determined from a combination of data on fish from all localities and without regard to date of capture, maturity, or state of organs. The curve is the graph of the length-weight equation; the dots represent the empirical values.

inches; all calculated weights were below the empirical weights at 8.9–11.9 inches and over the rather long interval, 16.1–20.0 inches).

The disagreements between empirical and calculated weights are reflected in the variations in the value of K. As stated previously, the length-weight equation indicates that K should increase as the 0.1523 power of the length.

The data of Table 27 do exhibit a general trend toward an increase in K with increase in length. This increase, however, was decidedly irregular. The outstanding disagreements were provided by the high values of K at 9.7 and 10.0 inches and the consistent decrease in the value of K over the interval, 9.7–12.4 inches.

Certain discrepancies between the calculated and empirical lengths and weights were to be expected. It will be brought out in the sections immediately following that the condition of the Lake Erie whitefish varies from month to month and that during the spawning season maturing and ripe females are much heavier in relation to their lengths than are males and spent females. These variations in combination with variations in the length distribution of fish in different samples account for the irregularities in the data of Table 27. The use of the equation to describe the general length-weight relationship of the Lake Erie whitefish, therefore, may be considered valid.

It was determined by means of the length-weight equation that the length corresponding to the minimum legal weight of 1¾ pounds (793.8 grams) was 365 millimeters, standard length, or 16.9 inches, total length.

Tabulations of the average values of K for the age groups of the various collections showed that differences in the average coefficient of condition of whitefish of different age could in general be attributed to differences in the average lengths of the age groups. The presentation of the K values for age groups will be limited to those involved in the study of seasonal fluctuations in condition (next section).

Comparisons of the values of K for whitefish of the same length but of different age and for whitefish of the same age but of different length failed to reveal a correlation between condition and the rate of growth.

Seasonal changes of condition.—Collections made off Erie, Pennsylvania, in 1928 and 1929 provide the only available materials suitable for the study of monthly fluctuations in the condition of Lake Erie whitefish (Table 28). By means of a combination of the data for the two years it was possible to trace the changes in the values of K for some age groups through the 6-month period, July-December.[28] Records of sex were available for only part of the fish. Where the numbers of specimens were fairly large, however, the sex differences in condition were small—especially in the youngest age groups. (Very few fish of age-group III and older groups, in which many to all fish were mature, were taken during the spawning period, November and early December, at which time K varies widely according to sex, and, in the females, according to state of organs—see next section.) Furthermore, the data for the sexes exhibited similar trends in the monthly fluctuations in the value of K. It appears valid, therefore, to describe the seasonal fluctuations in condition from the averages of K for the sexes combined.

[28] Comparisons of the 1928 and 1929 data for those months in which collections were made in both years indicated the combination to be valid.

TABLE 28.—*Condition* (K) *according to age, sex, and month of capture of the Lake Erie whitefish taken off Erie, Pennsylvania, 1928 and 1929*

[Numbers of specimens in parentheses]

Month	*K* according to age and sex													
	I			II			III			IV			V–XVI	
	M[1]	F[1]	Both	M	F	Both	M	F	Both	M	F	Both	F	Both
July	..	..	1.84	..	..	1.63	..	..	1.62	..	..	..	..	..
	..	..	(1)	..	..	(10)	..	..	(3)	..	..	..	..	..
August	..	..	1.96	..	..	1.78	..	..	1.78	..	..	1.80	..	1.86
	..	..	(2)	..	..	(14)	..	..	(87)	..	..	(37)	..	(3)
September	1.70	1.71	1.69	1.61	1.57	1.58	1.68	1.73	1.71	1.84	1.80	1.76	1.83	1.87
	(12)	(10)	(68)	(7)	(4)	(74)	(28)	(19)	(177)	(6)	(8)	(53)	(3)	(18)
October	..	..	1.46	1.65	1.41	1.56	1.69	1.59	1.68	..	..	1.71	..	1.76
	..	..	(3)	(4)	(2)	(13)	(1)	(1)	(185)	..	..	(68)	..	(18)
November	1.44	1.42	1.44	1.49	1.54	1.51	1.44	..	1.44	..	..	..	1.92	1.92
	(16)	(24)	(55)	(16)	(16)	(42)	(1)	..	(1)	..	..	..	(1)	(1)
December	1.37	1.42	1.40	1.46	1.46	1.46	..	..	..	..	..	..	..	..
	(15)	(22)	(38)	(14)	(15)	(29)	..	..	..	..	..	..	..	..
Average	1.49	1.47	1.54	1.52	1.50	1.56	1.67	1.72	1.71	1.84	1.80	1.75	1.85	1.82
	(43)	(56)	(167)	(41)	(37)	(182)	(30)	(20)	(453)	(6)	(8)	(158)	(4)	(40)

[1] M = male; F = female

The scanty evidence indicates an increase in the value of *K* from July to August. Condition seems to have reached the season's peak (for the 6 months) in the latter month, for *K* decreased rather consistently in the later months. In age-group I *K* declined from 1.96 in August (only 2 fish) to 1.40 in December. The corresponding decrease in age-group II was from 1.78 in August to 1.46 in December.

The values of *K* for the older age groups (III, IV, and V-XVI) indicate that through October, at least, whitefish that are predominantly mature suffer a decline in condition similar to that of immature fish. (In these collections all I-group and 96 percent of the II-group whitefish for which there were data were immature; 83 percent of the III group and all whitefish older than the III group were mature.) The average *K* of III-group whitefish decreased from 1.78 in August to 1.68 in October; the *K* of IV-group fish declined from 1.80 in August to 1.71 in October; and the *K* of whitefish older than age-group IV dropped from 1.86 (only 3 fish) in August to 1.76 in October (slight increase in September). These decreases were practically the same in the three groups, but were smaller than the decreases of *K* in age-groups I and II over the same period. Possibly the smaller decline in the *K* of the older fish was the result of the prespawning development of the gonads of the mature individuals. A decline in the condition of mature fish prior to the spawning season similar to that indicated by the data for these Erie whitefish was also reported by Deason and Hile (1947) for the kiyi of Lake Michigan.

Only two whitefish (an immature male and a ripe female) older than age-group II were taken in November. No fish of age-group III or older were captured in December.

Loss of weight at spawning.—No consistent differences were found between the weights of mature male whitefish of the same length but in different stages of sexual development [29] (Table 29). Maturing and ripe females were considerably heavier, however, than were spent females. The estimated loss of weight by females at spawning varied widely at different lengths with the percentage loss ranging from 1.1 to 20.9. These variations in the percentages were without a distinct trend and may be attributed chiefly to the small numbers of fish involved in many of the comparisons.

Three methods of estimating the grand average percentage loss of weight of females at spawning gave approximately the same result. The unweighted mean of the percentages was 11.4. If it is desired to take into consideration the number of fish, each percentage may be weighted by the product of the number of maturing and ripe and of spent females involved in the comparison. (For example, the percentage of 13.4 at 360–369 millimeters was given the weight, 9 x 11 = 99.) The average percentage obtained by this procedure was 11.0. Finally, the grand average *K* of spent

[29] Preliminary tabulations proved a combination of the length-weight data on spawning-run collections from different calendar years and different localities to be justifiable.

TABLE 29.—*Length-weight relationship of Lake Erie whitefish captured during the spawning run and the loss of weight of female whitefish at spawning*

[Data were combined for collections off Sandusky, Ohio, 1928 and 1929, and off Lorain, Ohio, 1929 and 1930]

Males (maturing, ripe, and spent)				Females (maturing and ripe)				Females (spent)				Loss of weight of females (grams)	Percentage loss at spawning
Number of fish	Standard length (millimeters)	Weight (grams)	*K*	Number of fish	Standard length (millimeters)	Weight (grams)	*K*	Number of fish	Standard length (millimeters)	Weight (grams)	*K*		
1	295	505	1.97	..	...	.....	....	..	...	.....	....	...	....
..	...	.....	....	1	306	595	2.08	..	...	.....	....	...	....
9	314	541	1.75	..	...	.....	....	..	...	.....	....	...	....
21	324	576	1.69	..	...	.....	....	..	...	.....	....	...	....
31	335	629	1.67	..	...	.....	....	..	...	.....	....	...	....
58	345	672	1.64	1	341	695	1.75	1	342	624	1.57	71	10.2
96	354	726	1.64	2	354	850	1.92	1	352	765	1.75	85	10.0
176	364	782	1.62	9	365	890	1.83	11	365	771	1.59	119	13.4
228	374	851	1.63	20	375	975	1.85	9	374	845	1.62	130	13.3
218	385	913	1.60	28	385	1,012	1.77	15	384	913	1.61	99	9.8
153	394	995	1.63	38	394	1,137	1.86	19	395	1,026	1.66	111	9.8
95	403	1,055	1.61	39	405	1,216	1.83	12	404	1,066	1.62	150	12.3
34	414	1,117	1.57	31	414	1,287	1.81	11	415	1,151	1.61	136	10.6
30	424	1,199	1.57	20	424	1,378	1.81	7	424	1,182	1.55	196	14.2
6	434	1,418	1.74	9	437	1,409	1.69	2	430	1,293	1.63	116	8.2
12	445	1,440	1.63	6	443	1,398	1.61	4	443	1,383	1.59	15	1.1
8	454	1,559	1.67	4	455	1,789	1.90	1	451	1,616	1.76	173	9.7
8	465	1,661	1.65	2	462	1,701	1.72	3	466	1,576	1.56	125	7.3
4	472	1,695	1.61	1	471	2,169	2.08	2	474	1,715	1.61	454	20.9
2	484	1,942	1.71	1	482	2,055	1.84	3	484	1,996	1.76	59	2.9
..	...	.....	....	1	497	2,245	1.83	1	490	1,894	1.61	351	15.6
1	500	1,928	1.54	2	509	2,070	1.57	..	...	.....	....	...	....
2	514	2,296	1.69	1	515	2,574	1.88	1	516	2,104	1.53	470	18.3
1	524	2,489	1.73	2	520	2,790	1.98	1	522	2,245	1.58	545	19.5
..	...	.....	....	1	539	2,559	1.63	..	...	.....	....	...	....
..	...	.....	....	4	545	2,784	1.72	1	541	2,509	1.58	275	9.9
1	550	3,048	1.83	..	...	.....	....	1	556	2,707	1.57	...	....
..	...	.....	....	1	574	3,113	1.65	..	...	.....	....	...	....

female whitefish was 1.618 or 10.7 percent less than 1.812, the grand average K of maturing and ripe females.

These three estimates lead to a general conclusion that female Lake Erie whitefish lose approximately 11 percent of their weight at spawning. This percentage should be recognized as minimal since some fish designated as ripe already may have lost some of their eggs and the evacuation of eggs may not have been complete in some fish designated as spent. The true percentage loss of weight at spawning probably is somewhat higher than 11.

The loss of weight of female whitefish from Lake Erie at spawning is a little below the value of 11.8 percent determined by Deason and Hile (1947) for female kiyis of Lake Michigan. These same authors estimated that male kiyis lost 1.6 percent of their weight (no loss could be demonstrated for male whitefish from Lake Erie).

Sex Ratio

Sex ratio in early autumn and among immature fish.—The estimation of the true sex ratio of the Lake Erie whitefish is handicapped by the circumstance that the bulk of the specimens for which there were records of sex were taken during the spawning run, at which time the sex ratio of many fish tends to be distinctly abnormal. A limited amount of information on the relative abundance of the sexes in samples of whitefish not from the spawning run was available from fish taken off Erie, Pennsylvania (Table

Table 30.—*Sex ratio in non-spawning-run samples of Lake Erie whitefish taken off Erie Pennsylvania, in 1928 and 1929*

[The November–December samples collected during the spawning period consisted of immature fish captured at a distance from the spawning grounds]

Months	Item	Age group						All ages
		I	II	III	IV	VI	VII	
September-October	Number of males	12	11	29	6	0	0	58
	Number of females	10	6	20	8	2	1	47
	Percentage males	54.5	64.7	59.2	42.9	0.0	0.0	55.2
November-December	Number of males	31	30	..	..	..	..	61
	Number of females	46	31	..	..	..	..	77
	Percentage males	40.3	49.2	..	..	..	..	44.2

30). Included in the table are records for immature whitefish of age-groups I and II captured in November and December in deep water at a distance from the spawning grounds.[30]

Males were in the majority in the September-October sample, but were in the minority in the November-December collections. The percentage of males increased from age-group I to age-group II in both the September-October and November-December collections. In the former collections

[30] The inclusion of these data seems valid since, as will be seen in a later section, all I-group and most II-group whitefish are immature. The data for the II group may have been distorted slightly by the absence of mature members of the age group.

the percentage of males decreased beyond the II group (females only in age-groups VI and VII). Scanty as the data of Table 30 are they suggest an approximately equal representation of the sexes in non-spawning-run samples.

Evidence for a nearly equal representation of the sexes in summer is offered by Pearl's (1916) observation that 386 or 45.9 percent of 841 whitefish captured off Dunkirk, New York, in large-mesh gill nets in early July were males. The percentage of males varied but little (from 43.2 percent to 48.3 percent) during the 5 days on which he made observations.

Sex ratio of the spawning run.—Males were strongly predominant in the spawning-run collections of the Lake Erie whitefish, accounting for 78.6 percent of all mature fish [31] captured (Table 31). The sex ratio varied rather widely, however, in the collections grouped by periods of a few days and in the combined samples for single years (Table 32). In the trap-net collections, for example, the general percentage of males ranged with year or port from 62.7 at Sandusky in 1928 to 90.4 at Lorain in 1929. This latter percentage it will be noted was considerably higher than the one for Sandusky in the same year (78.3 percent). The sex ratio varied considerably in different years even though the fish were taken in the same type of gear, off the same port, and at the same time of the year. Thus, for example, the percentage of males in trap-net samples taken off Lorain in 1929 and 1930 during the period, November 20–29, ranged from 60.7 to 94.5. The percentages differed also in the two gill-net collections from Sandusky (79.3 in 1927; 91.5 in 1929). These annual percentages for gill nets both exceeded the value for all fish captured (right of table), but in view of the great variation among the collections from trap nets it is not possible to conclude that a real difference exists between the relative abundance of males in samples from the two gears.

The data on the sex ratio of whitefish captured at various periods during November and early December (see body of Table 32) do not indicate that time of capture in the spawning season (see a later section for information on the course of spawning activities) had any important effect on the annual variations in the percentage of males. It is true that in the combined collections (right of table) the percentage of males decreased consistently from 83.1 during November 12–19 to 70.2 during December 4–7. This seeming trend is not convincing, however, in the light of the great variability in the percentage of males in samples collected in corresponding periods of days but in different years, off different ports, or by different gears, and the lack of consistent trends in the data for fish captured off a single port, in the same year, and by the same type of net. The general conclusion seems valid, therefore, that no great change took place in the sex ratio during the spawning season and hence that time of capture had no significant effect on the data on the ratio in spawning-run samples.

[31] Spawning-run collections were made up almost entirely of mature individuals. Only 13 immature whitefish (11 males and 2 females) representing age-groups I to III were taken along with the 2,037 mature fish on which the discussion of this section is based.

TABLE 31.—*Representation of the sexes according to age among mature individuals of spawning-run collections of Lake Erie whitefish*

[The trap-net collections were taken off Sandusky, Ohio, in 1927, 1928, and 1929 and off Lorain, Ohio, in 1929 and 1930. Collections from large-mesh gill nets were taken off Sandusky in 1927 and 1929]

Gear of capture	Item	Age group													All ages
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	
Trap nets	Number of males	1	129	721	165	16	4	3	..	0	2	1	..	0	0	1,042
	Number of females	1	2	131	140	24	13	2	..	3	4	2	..	3	1	326
	Percentage males	50.0	98.5	84.6	54.1	40.0	23.5	60.0	..	0.0	33.3	33.3	..	0.0	0.0	76.2
Large-mesh gill nets	Number of males	..	50	338	41	100	22	1	1	0	4	2	0	..	0	559
	Number of females	..	1	11	11	43	12	2	3	4	7	9	4	..	3	110
	Percentage males	..	98.0	96.8	78.8	69.9	64.7	33.3	25.0	0.0	36.4	18.2	0.0	..	0.0	88.6
Trap nets and large-mesh gill nets	Number of males	1	179	1,059	206	116	26	4	1	0	6	3	0	0	0	1,601
	Number of females	1	3	142	151	67	25	4	3	7	11	11	4	3	4	436
	Percentage males	50.0	98.4	88.2	57.7	63.4	51.0	50.0	25.0	0.0	35.3	21.4	0.0	0.0	0.0	78.6

TABLE 32.—*Percentage of males in spawning-run samples of Lake Erie whitefish according to gear of capture, port, year, and date within the spawning season*

[In parentheses is the numerical representation of the sexes with the number of males at the left and the number of females at the right]

Date	Trap nets					Large-mesh gill nets		All samples
	Sandusky 1927	Sandusky 1928	Sandusky 1929	Lorain 1929	Lorain 1930	Sandusky 1927	Sandusky 1929	
November 5–9	100.0 (1–0)	....	79.6 (203–52)	....	61.5 (8–5)	....	....	78.8 (212–57)
November 12–19	100.0 (2–0)	....	84.8 (206–37)	....	71.4 (80–32)	....	94.7 (71–4)	83.1 (359–73)
November 20–21	....	84.8 (28–5)	....	86.5 (77–12)	60.7 (54–35)	....	90.0 (144–16)	81.7 (303–68)
November 22–29	78.7 (59–16)	....	65.0 (93–50)	94.5 (52–3)	67.2 (45–22)	79.3 (344–90)	....	76.6 (593–181)
December 4–7	....	56.4 (66–51)	....	91.9 (68–6)	....	....	....	70.2 (134–57)
All dates	79.5 (62–16)	62.7 (94–56)	78.3 (502 139)	90.4 (197–21)	66.5 (187–94)	79.3 (344–90)	91.5 (215 20)	78.6 (1,601–436)
Average age	3.38	3.28	3.25	3.24	3.57	4.23	3.61	3.55

Differences in the age composition together with a correlation between age and sex ratio can be an important source of variation in the relative abundance of the sexes from one collection to another. That age and sex ratio are closely related in spawning-run samples of Lake Erie whitefish is apparent from the data of Table 31. In the trap-net samples the percentage of males decreased consistently from age-group II (the I group was represented by only two fish) through age-group VI and in the gill-net samples a similar downward trend existed from age-group II through age-group IX.[32] Except for an irregularity at age-group V (traceable to the strong representation of that age group in the gill-net collections which tended to include relatively more males than did trap-net samples) the combined trap-net and gill-net data also showed a downward trend in the percentage of males from age-group II through age-group IX. Males were generally scarce or lacking among the older age groups. Fish of this sex, 10 in number, made up only 18.9 percent of the total of 53 whitefish in age-groups VIII-XIV.

Despite the obviously close relationship between age and sex ratio indicated by the data of Table 31, it appears impossible to attribute all of the observed annual and local variations in the percentage of males to differences of age. It is true that in the gill-net collections (Table 32) the 1927 fish which averaged the older included relatively fewer males than did the 1929 collection. Furthermore, the highest percentage of males in the trap-net samples (90.4 percent at Lorain in 1929) occurred in the collection with the lowest average age (average number of annuli, 3.24). On the other hand, the collection with the lowest percentage of males (62.7 percent at Sandusky in 1928) averaged only slightly older (3.28 annuli) and the order of arrangement of the collections with respect to age and the percentage of males was by no means the same. A similar lack of close correlation between average age and sex ratio was observed for samples collected at different dates in the same year (data not given here).

The failure of time of capture in the spawning season and the average age of the fish to account adequately for the observed differences in the sex ratio of the several collections invites the assumption that a certain amount of segregation of the sexes takes place during the spawning period and hence that the ratio in a particular collection depends to a degree on whether it (or most of its component samples) happened to be taken from an area or school in which fish of a particular sex were especially plentiful. Support for this assumption is to be found in the observation that despite the fact that all collections exhibited a trend toward a decrease in the percentage of males with increase in age, the sex ratio nevertheless varied widely from one collection to another in a single age group. The original tabulations (not given here) revealed, for example, that the percentage of males in age-group III of the trap-net samples ranged from 66.2 to 91.1.

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[32] In both gears the samples for the individual years (and ports) exhibited the same general trends as the combined samples.

This variation followed a pattern in that all of the adequately represented age groups of a single year's collection shared the tendency to include a high or low percentage of males.

Of the numerous explanations that have been set forth in the literature to account for the tendency among fish for the females to become relatively more plentiful as age increases, selection on the basis of age at which sexual maturity is attained and selective destruction of the sexes in the fishery appear to apply best to the spawning-run samples of the Lake Erie whitefish. Van Oosten (1939) observed that in Lake Huron male whitefish attain maturity approximately a year earlier than do females. The available evidence suggests a similar condition in the Lake Erie whitefish (see next section). It would be expected, then, that the males which mature the earlier, should predominate in the younger age groups of spawning-run collections, but that the later maturing females should become relatively more abundant with increase in age. It should be pointed out further that the earlier occurrence of the males in the spawning run subjects them to the greater mortality from the fishery (capture and sale of legal-sized fish; destruction of young fish by confinement in trap nets, in the sorting of trap-net catches, or by capture in gill nets). This differential destruction of the sexes no doubt accelerates the rate of change of the sex ratio with increase in the age of the younger fish.

Available data indicate, however, that practically all if not all whitefish of both sexes are mature as age-group IV. Consequently, the preceding explanation cannot apply to decreases in the relative abundance of males in fish older than the IV group. The percentage of males did decrease, however, with increase in age beyond age-group IV.

This decrease in the relative abundance of males in the older age groups points toward a differential mortality of the sexes, other than that associated with sex differences in the age at first maturity. Conceivably this differential mortality may be natural, that is, females may have inherently a longer life span than males. The change in the sex ratio of older fish also can be the result of a tendency for males to remain longer or move about more actively on the grounds than do females and hence to suffer a greater mortality by fishing in addition to that associated with the earlier age at maturity.

Age at Sexual Maturity

Since most of the samples for which there are records of both sex and maturity were taken from the spawning run which consists almost exclusively of mature fish (less than 1 percent immature), it is not possible to give exact information as to the percentages of mature and immature individuals at different sizes and ages. The only available information from collections taken on dates outside the spawning season (Table 33) proves little more than that some males mature as early as the third year of life (age-group II) and that some fish of both sexes are still immature in the

fourth year of life (age-group III). All whitefish of these September-October collections older than age-group III were mature.

In spite of the great scarcity of immature whitefish in the spawning run, the study of the age composition of spawning-run samples does provide information as to the age at first maturity. Particular attention should be

TABLE 33.—*Numbers of mature and immature whitefish in collections taken off Erie, Pennsylvania, in September and October, 1928*

Age group	Males		Females		Immature with no sex record
	Mature	Immature	Mature	Immature	
I	...	...	...	...	4
II	3	4	0	2	1
III	18	1	11	3	1

paid to the trap-net samples since the meshes of trap nets were sufficiently small (2 to 3 inches) to retain whitefish of all age groups except the young of the year (0 group). The absence or scarcity of young fish in trap-net samples of the spawning run may be taken as evidence that the individuals of the poorly represented age groups are predominantly immature. The absence or scarcity of young whitefish from samples taken by large-mesh gill nets, however, may be attributed in part to the selective action of the gear.

The data of Table 34 indicate that whitefish are only rarely mature as age-group I (only 1 mature individual of each sex). Fair numbers of males but almost no females were mature as the II group (age-group II made up 12.4 percent of the total number of males but only 0.6 percent of the total number of females in trap-net collections). The fact that the III

TABLE 34.—*Age composition (percentages, with the numbers of specimens in parentheses) of mature whitefish for each sex and for the sexes combined in the spawning-run samples from Sandusky, Ohio, and Lorain, Ohio, 1927–1930*

[All data were based on trap-net collections]

Age group	Sex		
	Males	Females	Both sexes
I	0.1 (1)	0.3 (1)	0.1 (2)
II	12.4 (129)	0.6 (2)	9.6 (131)
III	69.2 (721)	40.2 (131)	62.3 (852)
IV	15.8 (165)	42.9 (140)	22.3 (305)
V	1.5 (16)	7.4 (24)	2.9 (40)
>V	1.0 (10)	8.6 (28)	2.8 (38)

group was dominant among the males (69.2 percent of the total number of males in the trap-net collections) suggests that practically all males were mature at the end of the fourth year of life. The III-group females, however, accounted for only 40.2 percent of the total number of females as compared with 42.9 percent for the IV group. This dominance of age-group IV suggests strongly that many—most probably a majority—female whitefish first reach maturity at that age. It is not believed that any substantial percentage of female whitefish first reach maturity at an age beyond the IV group. The greater percentage of females in age-group V and older (in comparison with the males) can be ascribed to the fact that females have the longer life span.

Since male whitefish mature at an earlier age than do females, attention must be given primarily to the females in the consideration of the proper size limit for the protection of immature fish. The fact that the III group is the youngest age group containing appreciable numbers (although probably not a majority) of mature female whitefish suggests that members of this age group at least should have full protection through their first spawning at the end of the fourth year of life. Unfortunately, practical considerations prohibit the recommendation at this time of a size limit based on such a simple, even though biologically sound, premise. From Table 35, which shows the percentages of individuals in the different age groups that would be protected by different size limits, it may be seen that limits affording protection to more than 80 percent of the spawning III-group females would permit the fishermen to keep only from 1 to 8 percent of all these III-group whitefish and from 11 to 40 percent of all IV-group fish.[33] Inasmuch as age-group III is normally dominant in the commercial catch, with age-group IV second in abundance, it is apparent that these biologically adequate size limits would leave the fishermen with an insignificant quantity of fish for the market. Certainly no good purpose would be served by the imposition of a size limit that protects the spawners but puts an end to the fishery.

On the other hand, the present size limit of 1¾ pounds (in the round) in the United States waters of Lake Erie[34] must be recognized as altogether inadequate. This limit protects only 8 percent of the spawning-run females of age-group III and only 21 percent of the age group as a whole. The least protection that can be recommended is that afforded by a 2-pound limit—the limit now in effect in all Great Lakes waters of the Province of Ontario and in the Great Lakes waters of the States of Michigan, Illinois, and Indiana. With this size limit the fishermen still could market 46 percent of all III-group fish and 87 percent of all IV-group fish. The percentage of spawning III-group females protected would be increased from 8 to 34, and the value of the undersized III-group whitefish would be

[33] The percentages of Table 35 for "All fish" were computed from the length frequencies of Table 14. The percentages for mature females were computed from a special tabulation of length frequencies not included in this paper. See Footnote 11.

[34] The size limit is 2 pounds in the State of Michigan waters but the production of whitefish is negligible in that portion of Lake Erie.

TABLE 35.—*Percentage of undersized individuals in the age groups of Lake Erie whitefish at different size limits*

[The length or weight equivalent to each size limit is given in parentheses]

Age group	Item	Size limit							
		1¾ pounds (16.9 inches)	2 pounds (17.6 inches)	18 inches (2.14 pounds)	18½ inches (2.34 pounds)	2½ pounds (18.9 inches)	19 inches (2.55 pounds)	19½ inches (2.77 pounds)	3 pounds (20.0 inches)
II	All fish	97	99	99	100	100	100	100	100
	Mature females[1]	100	100	100	100	100	100	100	100
III	All fish	21	54	69	86	92	94	98	99
	Mature females	8	34	49	72	81	83	92	98
IV	All fish	3	13	23	41	60	63	78	89
	Mature females	2	7	15	36	57	62	81	90
V	All fish	1	2	2	7	14	15	25	45
	Mature females	0	0	0	0	5	7	16	37
VI	All fish	0	0	0	0	3	3	7	14
	Mature females	0	0	0	0	4	4	4	8

Percentages for mature females in this table were based on spawning-run samples; almost no females were mature as II group

increased greatly by an additional year of growth. The possibility should be considered also that with a gradual increase of the size limit the abundance of older whitefish might be increased to a point at which a limit greater than 2 pounds would prove to be economically sound.

The problem of protecting the immature whitefish in the western part of Lake Erie is simplified somewhat by the circumstance that the bulk of the commercial production takes place during the spawning run. Since immature whitefish occur only rarely on the spawning grounds, the mere state of immaturity provides them protection. In the eastern end of the lake whitefish are taken chiefly during the summer. Here the smaller fish receive some protection from the circumstance that the principal gear is the large-mesh gill net which tends to take larger fish than do impounding nets. In this same eastern region, however, large numbers of immature whitefish formerly were destroyed by the small-mesh gill nets fished for the cisco. It is estimated that approximately a third of the early "cisco" catches was made up of small whitefish. Unquestionably this destruction would occur again should the stocks of the cisco recover sufficiently to warrant the resumption of fishing for that species.

Spawning Season

Records of the state of the gonads of spawning-run whitefish collected off Sandusky in 1928 and 1929 and off Lorain in 1929 and 1930 provide some information on the course of spawning activities. It is well known that the actual dates of the spawning season vary somewhat from year to year. Consequently the data on the state of the gonads at various periods within the spawning season originally were tabulated separately for each port and calendar year. The differences observed were without trend and so small

Table 36.—*Changes during the progress of the spawning season in the state of organs of adult Lake Erie whitefish in samples from the spawning run*

[Based on collections off Sandusky, Ohio, 1928–1929, and off Lorain, Ohio, 1929–1930]

Date	State of organs	Males		Females	
		Number of fish	Percentage	Number of fish	Percentage
November 5–6	M[1]	196	92.9	52	91.2
	R[1]	15	7.1	5	8.8
	S[1]	0	0.0	0	0.0
November 12–19	M	116	32.5	45	61.7
	R	206	57.7	23	31.5
	S	35	9.8	5	6.8
November 20–21	M	64	21.1	20	29.4
	R	186	61.4	30	44.1
	S	53	17.5	18	26.5
November 22–29	M	17	8.9	18	24.0
	R	121	63.7	18	24.0
	S	52	27.4	39	52.0
December 4–7	M	0	0.0	1	1.8
	R	107	79.9	12	21.0
	S	27	20.1	44	77.2

[1] M = mature but with organs not yet ripe; R = ripe; S = spent

that these original tabulations were combined to form Table 36. (See Table 1 for dates of collection in the different years at the two ports.)

The collections of November 5–6 contained no spent fish of either sex and only small percentages of ripe fish (males, 7.1 percent; females, 8.8 percent). Apparently little, if any, spawning occurred in the first week of November. Active spawning was underway, however, during November 12–19 and in later periods.

Certain of the trends in the changes in the state of the gonads from period to period during the spawning season were not the same for the sexes. It is true that the percentages of mature males and females both decreased consistently throughout the spawning season and that with one exception (males, December 4–7) the percentages of spent fish of both sexes increased consistently. The percentages of ripe males, however, increased consistently from period to period whereas the percentages of ripe females increased to a maximum of 44.1 percent on November 20–21, fell sharply to 24.0 percent during November 22–29, and suffered an additional decline to 21.0 percent in the final period, December 4–7.

The maximum percentage of ripe females (44.1 percent) on November 20–21 possibly may represent the peak of spawning activities. The presence of ripe fish during December 4–7 proves that spawning was not yet complete in the first week of December. Apparently the length of the spawning season is not less than a month.

The small representation of spent male whitefish (in comparison with the percentages of spent female whitefish) in all periods after November 12–19 is of interest. This relative scarcity of spent males suggests that male whitefish may require a longer period to spend themselves than do female whitefish or that males may be the less inclined to remain on the grounds as spent fish. The former explanation is in accord with the common belief that males remain the longer on the spawning grounds and with the fact that males ordinarily outnumber females at all periods of the spawning run.

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Part 11

Symposium

FISH AND WILDLIFE IN RELATION TO FLOOD-CONTROL AND NAVIGATION DEVELOPMENTS AND TO THE ELIMINATION OF POLLUTION OF PUBLIC WATERS

SYMPOSIUM

FISH AND WILDLIFE IN RELATION TO FLOOD-CONTROL AND NAVIGATION DEVELOPMENTS AND TO THE ELIMINATION OF POLLUTION OF PUBLIC WATERS

MR. HOGAN: Our program today provides for a forum of four speakers. These men represent varying interests, all of which have an important bearing upon our wildlife. We have brought them together here this morning in order that we in fisheries may learn some of the problems that are encountered by people in other fields, and so that those engaged in other aspects of water use may learn about the problems that we in fisheries are facing.

Where a few years ago we had a local saw mill we now have a large pulp mill that employs 5 or 10 hundred people, and where our streams at one time were clear and stable, we now have aggravated flood conditions. Where once we had small hamlets we now have growing cities with the problem of municipal sewage disposal. All of these changes have a vital bearing on fish life.

The first speaker on our forum is Lieutenant-General R. A. Wheeler, Chief of Engineers, Washington, D. C.

FISH AND WILDLIFE IN THE FEDERAL PROGRAM OF NAVIGATION AND FLOOD CONTROL

LIEUTENANT-GENERAL R. A. WHEELER
Chief of Engineering, U. S. Army

For more than a century the Corps of Engineers and the American fisherman have been closely united in a common interest. So I—an amateur fisherman, who in recent years has found too little time to slip off somewhere and wet a favorite fly—am doubly delighted to be here with you today—with the leaders of the two associations that have done such fine work in preserving and improving the American fish and wildlife.

Fishing has been an important American enterprise since the early days of the republic. The Corps of Engineers—as the agency charged since 1824 with all federal river and harbor improvements—naturally has been in continuous association with the fishing industry.

Important factors in justifying economically Congressional authorization for the numerous small-craft harbors along the Atlantic, Gulf, and Pacific Coasts have been the direct benefits derived from these harbors to our fishing interests. In the larger, more extensive improvements to our great ports, such as Boston, the benefits derived to our vast fishing fleets have been an important consideration. Consequently, the early ties between the Corps of Engineers and the country's fishing interests have been broadened through the years. Particularly has this been true as we have

developed the program of progressive improvement of our inland waterways, and as flood control—with the necessary construction of large reservoirs—has become more and more a national necessity as a federal undertaking.

Having in mind this long record of association, it was with great pleasure that I promptly accepted Mr. Hogan's kind invitation to meet with you in your joint session today. In such meetings there is much to be gained. Not only can we come to know one another better, but through mutual discussion of our common purposes and problems, we can work toward solutions best calculated to attain our common goal.

The federal navigation and flood-control program is an important part of a larger overall plan for the conservation, control, and utilization of our nation's water resources in the public interest. It is our firm policy that the Corps of Engineers, in carrying out its part of this overall program, shall cooperate to the fullest extent practicable with you and with others who have a vital interest in the preservation of the fish and wildlife resources as a public heritage.

Cooperation between our agencies on projects constructed by the Corps of Engineers has resulted in many important benefits to fish and wildlife. Examples of such projects are the Great Salt Plains Reservoir in north-central Oklahoma, the Sardis Reservoir in northern Mississippi, and the Upper Mississippi River navigation project from St. Louis, Missouri, to Minneapolis and St. Paul, Minnesota. Increasing benefits will, I am sure, grow from continuation of our joint efforts.

The Great Salt Plains Reservoir (which was placed in operation on the Salt Fork of the Arkansas River, in Oklahoma, in July 1941) has a permanent conservation pool of 10,700 acres. However, work on the Salt Plains National Wildlife Refuge in the reservoir area was initiated in 1930, as one of the first operations under the Migratory Bird Conservation Act. Plans for the refuge called for development by diverting water onto the area, but estimated costs were in excess of available funds. Later, the area was flooded by the Great Salt Plains dam built for flood control and the refuge area was materially increased by the addition of lands acquired for the flood-control project. In this way, the amount of conservation funds required for developing this important refuge area was materially reduced.

You are truly fortunate in having Dr. Ira N. Gabrielson, former director of the Fish and Wildlife Service, on your program today. If he will pardon me, I should like to quote a statement from his informative book, "Wildlife Refuge", published in 1943, a copy of which I keep in my office:

> The Upper Mississippi Wildlife and Fish Refuge Act, passed in 1924, authorized the Service to buy overflow lands of the Upper Mississippi Valley, but reserved navigation rights to the War Department. Subsequent to the purchase of much of the land by the Biological Survey, the channel-improvement project for making a nine-foot channel from St. Louis, Missouri, to the Twin Cities, Minnesota, was started. This called for construction of a series of dams to provide slack-water navigation for river traffic. It was assumed by many conservationists that this

would ruin the refuge and there was a great outcry about it. If the original plans had been followed, destruction might have resulted. However, after consultation with the Service, the Army Engineers so modified construction plans that the area, far from being destroyed, has been vastly improved. It would have been impossible for any conservation organization, operating solely for the benefit of fish and wildlife, to stabilize water levels as effectively as had now been done.

The Sardis Reservoir on the Little Tallahatchie River in northwest Mississippi was completed in 1940 for flood control. A permanent conservation pool of 9,800 acres is provided in the reservoir. The Mississippi State Game and Fish Commission estimates that approximately 750,000 pounds of game fish and 250,000 pounds of commercial fish are taken annually from the Sardis Reservoir. It is expected that this reservoir will continue to produce such large quantities of fish.

Thus, many of the projects constructed by the Corps of Engineers contribute materially to fish and wildlife. In addition, many of the projects provide opportunities for our great national sports of hunting and fishing and general outdoor recreation. As the flood-control and navigation programs progress, there will be need for continuing and extending the cooperation which has made these benefits possible.

The President in his message to the Congress 16 July 1947 stated:

> The major opportunity of our generation to increase the wealth of the nation lies in the development of our great river systems. I urged in the State of the Union message on January 6, 1947, that the program for improvement of our waters be pushed with full vigor.
>
> Since that time, the urgency of one phase of our water resources control program has been demonstrated forcefully and tragically. Vast areas of the most productive sections of the Missouri and Upper Mississippi River valleys have been subjected to a series of the most destructive floods in our history. Too frequently within our memory, as well as in earlier years, the Mississippi River Basin has been similarly stricken. This continued threat and the recurring and accumulative damage to the national economy and well-being call strongly for the prompt use of more effective counter-measures. Prudence requires that adequate measures be taken for protection against these devastating floods.
>
> Measures for flood control should be integrated with plans for the use and conservation of water resources for other purposes. This will insure maximum control of floods at the least cost and will permit the full utilization of water resources in the development of this vast region.

The toll of life and property taken by floods is of national concern. Flood-control and navigation programs must go forward for the security and continued prosperity of our people. In carrying out these programs, I assure you that every effort will be made to obtain all other benefits possible.

Congress appropriated $415,553,525 for flood-control and navigation work during the fiscal year ending June 30, 1948. Of this amount, almost $300,000,000 is for flood control, which will make possible the most concerted progress to provide the American people with this greatly needed type of protection, in the 10 years since flood control generally was accepted as a federal responsibility. In addition to work on the Lower

Mississippi River and on the Sacramento River, the appropriation act permits construction on 156 projects located in 35 states.

The Corps of Engineers shares with all of you a responsibility for cooperating in this immense program for the development, control, and utilization of the water resources of the nation, to insure that the maximum overall public benefits will be obtained from each project. To aid in that cooperation, I should like to review briefly the procedures and policies which are followed in the development of the Corps of Engineers' plans and programs for flood control, navigation, and allied benefits.

To carry out efficiently and expeditiously the planning, construction, and operation of flood-control and navigation projects, the Corps of Engineers is decentralized into responsible local units. The continental United States is covered by 11 Engineer Divisions, with each division embracing certain watershed areas. Each division is subdivided into Engineer Districts. At present there is a total of 39 Engineer Districts in the continental United States. The districts are the organizational units closest to the people affected and, accordingly, are responsible for carrying out the investigations, the preparation of engineering plans, and the construction and operation of the projects. They are also responsible for coordinating these activities with state and local agencies, and with regional offices of other federal agencies.

Flood-control and navigation projects are investigated, constructed, and operated strictly in accordance with laws enacted by Congress in various Food Control and River and Harbor Acts and other legislation. These laws, which have been passed by Congress over a period of years, taken all together, establish a very definite and sound federal policy. Under this policy, the Corps of Engineers is responsible to Congress for investigations and improvements of rivers and other waterways for flood control and navigation. Comprehensive and coordinated development is mandatory; rights of the states and interests of the people are recognized and protected; and all flood-control and navigation investigations and improvements must be economically justified and authorized by Congress before they are undertaken.

The investigation and planning of projects for waterways improvements begin at the "grass roots". They are initiated by the people in the different localities through their representatives in Congress on the basis of experienced needs. At the direction of Congress, preliminary investigations are undertaken by the Corps of Engineers. In these studies the Corps acts as an expert engineering consultant to the Congress, and in that capacity advises the Congress on the relative importance, need, urgency, benefits, and soundness of a proposed improvement. The investigations include public hearings in the local areas. These hearings are designed to invite full civic participation and discussion, and to give individuals and organizations full opportunity to express their views. Our reports to Congress include the evidence presented at the hearings, as well as written testi-

mony from the people most affected by the existing problems and the proposed improvements.

Our reports to Congress include also the views of many other agencies relative to the phases of the improvement in which those agencies are interested. Every effort is made to plan all flood-control and navigation improvements as a part of a comprehensive program in cooperation with other agencies for the utilization of our natural resources for the maximum public good.

This effort involves consideration of many collateral problems, including fish and wildlife, stream-pollution abatement, municipal and industrial water supplies, soil conservation, irrigation, hydroelectric power, and other related matters. It is not the policy or intention of the Corps of Engineers to create a working organization which will duplicate the efforts or act in competition with existing state and federal agencies. Consequently, in considering plans for waterway improvements, the Corps consults with all interested local, state, and federal agencies to obtain the best advice and assistance possible to insure that the projects will provide the maximum possible overall public benefits. Much valuable assistance has been obtained in this manner from fish and game authorities.

When Congress appropriates funds for the construction of a reservoir, extensive study is given to the exact determination of the project's features. Included among these many features, the following are of particular interest to fish and wildlife authorities: pool elevations; land required; reservoir clearing; location and design of appurtenances to be incorporated into the project structures for fish and wildlife; and pre-impoundment work in the reservoir area for fish and wildlife—such as the tying down of brush, the improvement of fish spawning areas, and the sowing of aquatic plants for wildlife feed. At this stage, the views and recommendations of fish and wildlife authorities are particularly desired.

Many reservoirs provide large, permanent, artificial lakes incidental to the storage of water for the primary purposes of the project. At other reservoirs, permanent pools are provided wherever practical and desirable for fish and wildlife purposes, recreation, and other uses. To provide for fluctuations of the reservoir's surface, and to avoid severance of individual properties, fringe lands are acquired above the permanent and normal pool elevations. Some of this land is subject to only infrequent inundation, and careful consideration is given to its use, as well as to areas within the reservoir itself for other purposes. Wherever collateral uses such as agriculture, forestry, fish and wildlife conservation, and recreation are not inconsistent with the operation of the project for its primary purpose, they are developed as an integral part of the project.

To assure an orderly development and use of a reservoir under a sound management program to obtain the maximum, overall public benefits, our district engineers prepare master plans as guides for the administration of the area. In these plans, primary consideration is given to the needs of the general public. Private exploitation and despoilment of the areas

under the control of the War Department are not permitted. Lands more valuable for public use are not leased for private cottage sites, private camps, or for commercial purposes. Private or exclusive fishing or hunting privileges are not granted. Public hearings are always held in connection with the development of these plans, so that the views of all interested groups may be heard.

The Corps also has a real responsibility in administering these projects so that these important collateral uses are made available to the public. We cannot, however, do this work alone. The collateral benefits to be obtained from a project are usually much more important to the state and local areas than to the nation as a whole. Accordingly, I strongly urge that the state and local agencies who have responsibilities for recreation, fish and wildlife, and related matters participate with the District Engineer in the preparation of the master plans and in carrying out these plans.

The Corps of Engineers does not desire to assume responsibilities for the administration of fish and wildlife management programs, or to operate and maintain public park aand recreational facilities. It is only through the combined cooperative action of all interested agencies—in which each agency performs those functions for which it is particularly qualified—that the maximum benefits to the people can be realized. Accordingly, it is our desire that these agencies undertake various phases of the reservoir development for collateral uses under a sound management plan.

With fishing and hunting an important part of the public activities on the reservoir areas, the development and maintenance of the fish and wildlife resources are a very important part of any master plan. An indication of the importance of fishing in these reservoirs is the fact that the merchants and businessmen of Denison, Texas, and other communities in the region are sponsoring a fish rodeo this year at Lake Texoma and have offered $75,000 in cash and prizes. Anglers from all parts of the country are competing for this prize money.

There will be considerable areas of land in public ownership at most of these reservoir areas, and this land will offer possibilities for fish and game management programs, and for public hunting and shooting areas. The state fish and game authorities and the Fish and Wildlife Service are encouraged to manage the fish and wildlife resources on these areas to the fullest extent possible. In a number of projects, large areas already have been turned over to the Fish and Wildlife Service for the establishment of refuges. Other areas have been turned over to the states to manage as a part of their fish and wildlife conservation program. Still other areas are being managed by the states on a less formal basis without a formal agreement. In many such cases, however, licenses have been granted to the states for relatively small areas for the establishment of their headquarters on a reservoir. In any situation, the Corps of Engineers desires to establish a mutually acceptable arrangement whereby the fish and wildlife authorities manage the wildlife resources on the reservoir areas.

The Corps of Engineers is endeavoring constantly to improve its pro-

gram of reservoir management. Two improvements of special interest on which we are currently working might be mentioned here. We are now completing arrangements with the Soil Conservation Service, under which that service will survey the lands under the control of the War Department, and will submit recommendations relative to the areas to be leased for agriculture and the type of agricultural use which may be permitted. Leases will be granted in accordance with these recommendations, and the lessee will be required to use the land in accordance with good soil-conservation practices. Steps are now underway to incorporate in the agricultural lease forms conditions that require the lessee to cooperate in fish and wildlife management programs, and also, when desirable, make the leased premises available for public hunting.

The construction and operation of flood-control and navigation projects involve so many conservation and related matters, it is natural that a wide variety of opinions should emerge. We do not object to differing opinions. The expression of one's opinion is a prized right of American citizens. As I stated to you a few minutes ago—and have stated to all groups to whom I speak—we encourage the voicing of individual views in all of our investigations. However, we—like you and all groups and individuals—do object to destructive, acrimonious criticism that is without basis in fact. I refer to statements that the Corps of Engineers does not care what destruction its projects wreak on fish and wildlife. I assure you that the Corps of Engineers is very much concerned with the effect of its projects on fish and wildlife, and that it is our continuing purpose to see to it that maximum benefits are obtained for those collateral uses consistent with our primary responsibility for river and harbor improvements and flood control.

At the risk of repeating myself, I should like to underscore this fact: *The interest of the Corps of Engineers in the fish and wildlife phases of its projects is not separate or apart from its constant and continuing interest in the other phases of its work.* Where the primary purposes of our projects, as authorized by the Congress, conflict with those of collateral interests, consultations should be held to reconcile the differences. Any basin-wide development necessarily affects many interests and the welfare and desires of many people. Conflicting interests are certain to arise. Experience shows that we cannot give to each group everything it wants. There always must be compromises. Full consideration can be given to all conservation matters only with the active and tolerant help of all concerned. The Corps of Engineers looks to organizations such as yours to help resolve differences that may exist, to recommend adjustments that are reasonable and fair to all concerned, and to promote a cooperative, constructive approach to a sound solution of these difficult problems.

This is a dual responsibility, and I want you to feel free to call at the District and Division Engineers' offices, or at my office, to discuss matters of mutual interest. Since the District Engineers are largely responsible for the planning, construction, and operation of the projects, I suggest that

detailed problems be taken up directly with them. I am certain you will find the Army Engineers very cooperative in solving and correlating problems pertaining to fish and wildlife in conjunction with the planning, construction, and operating of a Corps of Engineers project.

So let us continue to work together, and to solve our problems as they arise in collective, constructive actions. In this way only can we accomplish fully the tasks assigned to us.

MR. HOGAN: I am sure our Society and the International Association appreciate the time and effort that the General has put into his talk, and I hope that much good will come from his appearance here this morning

MR. KENNETH REID: I would like to know if I understood the General correctly in the statement that private concessions were not granted on waters such as those of the Upper Mississippi River. I believe he will find there have been a number of leases to private duck clubs that have interfered with the management of that area and have barred the public from hunting and given the benefit to private groups.

GENERAL WHEELER: My statement is correct. If there have been any such permits I would like to know to whom they were issued, and I will look into the matter.

MR. REID: I shall be glad to furnish the details. One other thing, purely as a point of information. What is the authority of the Engineer Corps to engage in agricultural drainage, or drainage of land for agricultural purposes?

GENERAL WHEELER: That authority belongs to the Department of Agriculture, but we make a cooperative study with them on every drainage project.

MR. REID: Isn't drainage the antithesis of flood control when you are working the same watershed—drainage and dam-building?

GENERAL WHEELER: Yes, and that is the reason we coordinate our projects; we work very closely with the Department of Agriculture. Their regional staff and our staff work closely together; our plans and theirs are exchanged, and we do some of their survey work for them.

MR. REID: We feel that flood control is one thing and drainage is another; that one defeats the other, and that too many flood-control projects, when you analyze them, are actually drainage projects which merely aggravate flood conditions in the whole valley below.

GENERAL WHEELER: The comprehensive flood-control plan is designed basically to control the flood discharge.

MR. REID: Our principal criticism of many of these flood-control plans is that actually drainage forms a major part. We have had to oppose numerous projects on that basis. An outstanding example I think of at the moment is the Illinois plan by which 156,000 acres of the Illinois River bottoms were to be drained and the river hemmed into a narrow channel between the levees, in spite of the fact that many drainage districts in the Illinois Valley are now financially defunct; then to offset that aggravation of floods it was proposed to build 14 dams on the Sangamon and other tributaries.

GENERAL WHEELER: You are talking about a report which has not been approved. As I explained in my paper, the state and other interests are asked to express their views. The report has not yet reached me. Until the field work is finished I shall not know what that report is finally going to contain.

MR. REID: I would like to know where drainage comes into flood control.

GENERAL WHEELER: I have the chief of my flood-control department here; perhaps he will answer that.

MR. GEORGE L. BEARD: Congress has declared in the Flood Control Acts that drainage through channel improvement is part of the definition of flood control. Land is often more or less permanently flooded; drainage of that land and control of the flooding are one and the same thing.

Mr. Reid spoke of the Putney Slough area in South Dakota. That report like the Illinois River report, is in the early stages of preparation. The Omaha district in its consultations, conferences and meetings with the local people inevitably has run into controversy between the conservation and fish and wildlife interests and the farming interests. We are trying to devise a scheme which will finally satisfy everybody. If we fail we will then have to report the facts to Congress. We do absolutely nothing without the direction of Congress.

MR. KAUPANGER: So far as the War Department is concerned the Missouri project is entirely a flood-control and navigation project; isn't that correct?

GENERAL WHEELER: No, sir; that is not correct.

MR. KAUPANGER: Then how do you account for the statement of your office before the House Wildlife Subcommittee in June 1946 when your assistant made the statement that it was a flood-control and navigation project?

GENERAL WHEELER: It is a comprehensive plan in which these are two of the benefits. Another is power development. Further, all these big dams have enough water for use for other purposes. There will be recreation in all the big pools, and water for irrigation also.

MR. KAUPANGER: Isn't it a fact that you are going to draw down those lakes 15 feet a year—for instance at Garrison?

GENERAL WHEELER: We are going to draw them down in accordance with a definite plan. First let me say that we are studying these projects in accordance with an Act of Congress which says that we shall investigate each site for every use of water. Our reports therefore are not limited to flood control and navigation. As to the drawing down of the pools, we make up a plan with certain top levels for flood waters and certain levels for other purposes.

MR. BROWN: Is it true, as was stated to me by one of your officers, that the Liberty Bend cut-off and the dikes and levees proposed for construction east of Kansas City will reduce the water level in the industrial district at Kansas City approximately 2 feet under any given conditions? As I understand it, that reduction is to be accomplished by taking water away more quickly and confining it; but by the same token would it not be carried down the river to Lexington, Marshall, Booneville, and Jefferson City faster and in larger quantities, thus creating more serious flood conditions there than exist under present conditions?

GENERAL WHEELER: Those constructions will put more water downstream, but the comprehensive plan provides for protection downstream by means of reservoirs on the tributaries below Kansas City which in combination with the levees will protect the cities you mention. No plan is recommended by us to Congress for approval unless it protects the entire basin.

MR. BROWN: But the work at Kansas City will be completed long before that further down on the river will be undertaken.

GENERAL WHEELER: That is unfortunate if it turns out to be true. We try to get the appropriations to carry the work forward in a coordinated manner, but it doesn't always work out that way. We ask for appropriations, but when action is finally

taken certain requests may not be granted. So we may get an appropriation for the Liberty Bend cut-off but not for the projects below Kansas City.

MR. BROWN: Isn't the Wappapello Dam on the St. Francis, just completed, an utter failure, and haven't the Army Engineers so stated?

MR. BEARD: It is far from a failure. That project is one part of a program for controlling the St. Francis River. The program as authorized contemplated levee reconstruction so that the flow developed from the reservoir could go safely down the river. The land owners, however, have refused consistently to permit the levees to be set back; therefore the project has always had to be operated in an entirely different manner from that for which it was designed and constructed. The present operation has been the best that could be devised under a partly completed scheme. It has not been as fully effective as many people expected, and it never will be until these levees are set back.

MR. CHURCH: You mentioned a few minutes ago, General, that a responsible agency would take into consideration the needs of the various interests. I would like to ask what agency passes on the need for further navigation on a river. Senator Reed of Kansas is on record in a speech given in 1939 as saying that some responsible agency of government should pass on the need for further transportation on the rivers. On the Columbia and Snake Rivers it is planned to spend $540,000 to provide river transportation to Lewiston, Idaho. We are vitally interested in that project, and as yet we have found no one who would say that the actual need was there.

GENERAL WHEELER: The Corps of Engineers reports upon any project as Congress directs. In submitting that report we estimate the cost of the project, the potential amount of traffic, and the savings that would result from the use of the waterway. If the annual savings exceed the annual cost, it is recommended by our corps as a worthy navigation project.

May I add this: On the great mid-continent system consisting of the Mississippi, the Ohio, the Illinois, and the Missouri Rivers, the connecting inter-coastal waterwaay, the traffic grew from some 9 billion ton-miles before the war to almost 32 billion ton-miles during the war. Big steel companies, coal companies, and oil companies all use waterway transportation. Water transportation is the very cheapest form of transportation, and for certain commodities it is of great benefit in the savings to the community. As an example, in the Upper Mississippi River canalization project, on which some 15 years ago I was a district engineer, the estimates on the savings have been greatly exceeded by actual experience. The same has been true on every one of our waterways.

THE PULP AND PAPER INDUSTRY'S STREAM-IMPROVEMENT PROGRAM

RUSSELL L. WINGET

National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries) Inc.

First I would like to tell you something of the aims and purposes of the organization which I represent. The National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries) Inc. was organized by these industries to conduct research looking to the solution of the industry's waste-abatement and utilization problems and to make the re-

search findings applicable to actual pulp- and paper-mill operations. The organization grew out of the industry's recognition of the necessity for studying its stream-improvement problems and the importance of preserving available water resources for industrial, public, and recreational usages.

To carry out the aims and functions of the Council, research programs have been established at 10 outstanding institutions: the Mellon Institute of Industrial Research, Virginia Polytechnic Institute, Manhattan College, Louisiana State University, the Institute of Paper Chemistry, Oregon State College, Rutgers University, Purdue University, the University of Michigan, and Kalamazoo College. The projects at each of these institutions deal with one or more pollution problems of importance to the pulp and paper mills in the area in which the research institution is located.

Our organization includes within its membership firms accounting for more than 85 percent of the pulp, paper, and paperboard production in the United States and operates on an annual budget of $150,000. Certain rigid policies have been established by our Board of Governors which are worthy of mention: non-interference in political and legislative matters; a two-fold research program of abatement and utilization, with the greater effort placed on abatement activities; the maximum degree of cooperation with state and other regulatory agencies; and the development of a sound industrial water-usage policy with due regard to the public and private equities involved.

The question probably occurs to you: Why is this extensive research program necessary and why cannot techniques currently in use for treating sewage or municipal wastes be applied to pulp- and paper-mill wastes? The answer is that pulp- and paper-mill wastes are of a highly complicated chemical nature differing widely from domestic wastes in many important characteristics. Their treatment accordingly requires new and specially developed techniques and equipment. Furthermore, it must be realized that industrial-waste treatment is relatively a new art, whereas the efficient treatment methods applicable to municipal sewage have been developed over a long period of years. We are making fairly rapid progress in our research program, as might be expected when it is understood that in our combined research projects we are making use of the services of over 50 scientists and technicians specially trained in this field. Our employees include specialists in many fields of scientific endeavor including sanitary engineers, chemists, biochemists, chemical engineers, biologists, microbiologists, bacteriologists, civil engineers, and stream sanitation experts, many of whom are nationally known in their fields.

According to the 1939 report of the National Resources Committee, pollution in the United States comes from three major sources: (1) municipal sewage; (2) mining and oil-field wastes; (3) industrial wastes. In this latter category are included wastes from the food-processing and beverage, textile and tanning, chemical, petroleum, iron and steel, rubber, and pulp and paper industries.

Both municipal and industrial wastes and also pollution such as silt

and other debris of natural origin may, under adverse circumstances, contribute to the development of an unhealthy aquatic environment. Most important of the resultant conditions are the depletion of the normal oxygen in the stream so that fish life can no longer be maintained, and the concentration of toxic substances to the degree where they may become a menace to fish and other aquatic organisms.

The depletion of oxygen in a stream results largely from the decay of putrescible substances as, for instance, sewage solids and food-product wastes. Many industrial wastes also have this oxygen-consuming character, known as "biochemical oxygen demand," or simply B.O.D.

In general, the concentration of toxic materials in a stream does not often reach the level such that it will cause the death of fish, as quite frequently they are able to develop at least a partial immunity to those substances and counteracting influences frequently prevent toxic materials from achieving dangerous concentrations.

It must be understood that individual streams vary widely in their ability to absorb pollution without harmful effects. The important factors here are volume and concentration of the wastes discharged, the volume of flow in the stream, and the temperature of the receiving waters. At the higher water temperatures of summer, the decay is rapid and unfortunately during this period stream flows are seasonally low. The study of this whole problem is complicated by the fact that it is extremely difficult in most situations to tell exactly what causes the death of a particular fish. Even autopsy of a fish sometimes fails to disclose the exact cause of death. The tendency generally is to jump at conclusions and blame the mortality on some industrial establishment on the river. Actually, however, the fish kill could result from any one of a number of causes, including natural mortality.

Sometimes the presence of municipal and industrial wastes is blamed for the gradual decline of fishing in a stream. Here, too, other factors enter the picture. Fish runs in the same river may vary from year to year and no one can predict what conditions are going to prevail in any given year. This uncertainty, perhaps best illustrated by the classic phrase "fisherman's luck," is probably one of the factors that makes fishing so attractive to the sportsman although a gamble to the commercial fisherman. Also, of course, there is the cumulative effect of overfishing, as has been illustrated by the decline in the shad run in the Hudson River, blamed at first on pollution largely from New York City sewers, but later, I believe, attributed in part to overfishing. If my information is correct, shad fishing in the Hudson River has shown a considerable improvement since control measures aimed to prevent overfishing were instituted.

I should like to describe briefly some of our research in connection with pollution problems that may affect fish and aquatic life. I should emphasize the fact that all of our activities were originated for the purpose of investigating and applying methods of reducing pollution. Obviously any

measures that reduce pollution will have a beneficial effect on fish and fishing. The time allotted to me does not permit a detailed discussion of each of our projects. I will limit myself therefore, to those activities which are directly associated with fishery problems. I will comment first on the oxygen-depletion problem.

Wastes from certain types of pulp mills have a high B.O.D. The problem here is to find some reasonably economic method of satisfying this oxygen demand before the waste is discharged. One of our methods of approach involves the use of the trickling filter, a device commonly used in the treatment of municipal sewage. By this device waste liquor is treated and the B.O.D. is satisfied before the liquor passes to the receiving waters. We conducted a 5-year series of researches on the use of the filter in treating waste sulphite liquor at the Institute of Paper Chemistry in Wisconsin at an expense of some $50,000. This research progressed from the laboratory stages to a large-scale pilot plant at a Wisconsin pulp mill. We found that considerable reduction in B.O.D. could be obtained through this device but that at present efficiencies, cost of construction for a filter to handle the entire effluent from a mill would approach the cost of the mill itself. At present, attention is being given to increasing the efficiencies of the device so it may be more practical.

We also investigated, at Oregon State College, the possibility of producing fodder yeast from waste sulphite liquor since it was known that by using the sugars in the wastes to produce yeast, a considerable reduction in the oxygen demand of the wastes could be expected. You will be interested to know that a plant to produce yeast from waste liquor is now under construction in the Middle West, and it seems to us that this process holds some promise. Our research is continuing at Oregon State College and our problem undoubtedly will be to produce yeast at a price that will compete with yeast produced from other materials and with other high-protein feeds so that the plant can be maintained in continuous operation irrespective of fluctuating prices. At Rutgers University we are conducting laboratory research to determine the feasibility of reducing oxygen demand of wastes by the foam-phase treatment and, in cooperation with the University of Michigan and Kalamazoo College, we have just put into operation a large-scale pilot plant to investigate the possibility of reducing the oxygen demand of waste liquors by aerobic decomposition. I am sorry that time does not permit me to cover these important projects in more detail but if any of you are interested in the technical details I shall be glad to make copies of our research reports available to you.

The treatment methods I have just described are admittedly in a developmental stage and are not as yet ready for general application. Pending their further development it has been necessary in emergency situations to apply available methods to existing pollution even though in some cases they may not be either permanent or economic solutions to the problems involved. In this connection we have attacked the problem of

oxygen depletion in a new and novel manner in Wisconsin. Here, with the cooperation of the Wisconsin State Department of Health, we are experimenting with the artificial reoxygenation of rivers subject to pulp-mill pollution. This process consists simply of passing large quantities of air through diffusers installed in the bed of the river below the mill outfall. This procedure has yielded very encouraging results. Under certain conditions the process offers a simple solution to a difficult problem. Another emergency device is the retention lagoon. Originally, lagoons were used to provide retention of wastes either permanently or during periods of low river flow. Recently, however, sanitary engineers have developed methods whereby, under certain conditions, with microbiological methods, the pollutional effects of the stored wastes can be greatly reduced or even eliminated. This method has been used with great success by a pulp and paper mill located on the Angelina River in Texas where extremely low summer flows presented a major problem.

In connection with toxicity problems, we maintain an aquatic-biology project at the Institute of Paper Chemistry at an annual cost of $10,000. This project has been under way for several years under the direction of Dr. Willis Van Horn, biologist. Originally the project was set up to determine the toxic effects of pulp-mill wastes on species of fish native to Wisconsin. This phase of the work was accomplished by segregating live fish in tanks under controlled conditions, subjecting them to various concentrations of mill wastes and observing the results. The same procedure was followed with typical fish-food organisms. Later, the work was expanded to include analyses of mill sewers for the purpose of developing methods for detecting toxic constituents in the mill waste and the development of automatic electronic warning devices to indicate the presence of toxic compounds in dangerous concentrations.

In 1947, an aquatic-biology program was instituted at Oregon State College under Professor R. E. Dimick. It was felt advisable to undertake work in the Pacific Northwest, a region with a heavy concentration of pulp and paper mills and an important commercial-fishing industry on the Columbia River and elsewhere. The work will be similar to that at the Institute of Paper Chemistry with special consideration given to the conditions existing in this area. Of chief importance among the special conditions in the Pacific Northwest are the tremendous flows in the great rivers of the area which make the development of dangerous toxic levels unlikely. During this summer a large and very important phase of the work is being carried on at the College's Marine Laboratory at Yaquina Bay.

I have mentioned only research projects related directly to fish problems. I would like to repeat, however, that all of our projects are concerned with the development of methods of reducing pollution from pulp and paper mills. As techniques are made available for actual mill operation, a reduction in paper-industry pollution will be made possible to the benefit not only of the public in general but of the fisherman in particular.

Because I have stressed the importance of our research activities, it must not be understood that the industry is depending on an elaborate research program alone to solve the problem. Great progress has been made by the industry in the last 10 to 15 years in reducing the volume and concentration of waste discharge. Increasing costs of materials, scarcity of water, and a consciousness of the public demand for improved disposal practices have resulted in a tremendous improvement in the situation. Losses of fibre and chemicals that were common a few years ago are no longer tolerated and increasingly the emphasis is on better utilization of waste materials.

In conclusion I would like to make a few general observations regarding the over-all pollution situation in the United States. I do not think that the onus for our present situation can be placed on the negligence, carelessness, or willful disregard of any one particular group. Rather, it seems to me that the problem has been developing for many years along with the growth of our population and our industrial expansion.

A century or so ago, stream pollution was not a problem because our rivers were large enough to carry off the wastes produced, without harmful effects. Of course then, except for a few large cities, our population was scattered and the disposal of human wastes was taken care of by primitive methods. Industrial establishments were of a local nature employing only a few workers and many industries that are among our largest today, such as petroleum refining, rubber manufacturing, and certain chemical industries, did not even exist.

The end of the Civil War saw the start of an industrial expansion such as the World had never before seen, and at the same time marked the beginning of an era of population increase that was without parallel in the history of any other nation. Since the capacity of our rivers remained unchanged our pollution problem began to assume serious proportions.

Since 1930 there has been another period of tremendous industrial expansion which I would like to illustrate by a few statistics indicative of activities in the food-manufacturing, textile, tanning, chemical manufacturing, petroleum, iron and steel, rubber, and pulp and paper industries, all of which incidentally were included in the references of the National Resources Committee to industries contributing to pollution.

Paper and paperboard production in 1930 was approximately 10,000,000 tons, while it is expected that production in 1947 will reach the all-time high of 20,000,000 tons, an increase of 100 percent in 17 years. Between 1930 and 1945, the last year for which I have data, production of manufactured food increased 50 percent and textile manufacture increased 100 percent. Tanneries processed 31,000,000 cattle hides in 1941 (the last pre-war year) as compared to 20,000,000 in 1934, an increase of over 50 percent in 7 years. Between 1930 and 1945, chemical production increased 230 percent. Petroleum production between 1930 and 1944, the last year for which I have data, increased almost 100 percent, and between 1930 and 1947, iron and steel production increased 100 percent and the

manufacture of rubber products rose 170 percent.

I think you will grasp the significance of the figures I have just quoted. Certainly they illustrate the fact that in order to maintain the highest standard of living the world has ever known we are, in this country, producing almost fantastic quantities of manufactured goods such as automobiles, household electrical devices, radios, manufactured food products, and other items, many of which were unheard of or not in common use even a generation ago.

Perhaps this change can be best illustrated by developments in the paper industry.

Since 1940 probably most of us have been affected by the "paper shortage" in one form or another. The minor inconveniences caused by these shortages lead us to speculate on what would happen to our economy if our paper supply were drastically reduced, for instance, cut in half. The pulp and paper industry today ranks sixth among the country's manufacturing industries and produces nearly twice as much paper as the rest of the world combined. Paper consumption in the United States in 1900 was 57 pounds per capita; in 1930, it had increased to 200 pounds, and in 1947 it will reach the phenomenal level of 350 pounds per capita. This per capita consumption is almost seven times that of 55 pounds in Great Britain which fact to some extent indicates the vast difference between our "high, wide, and handsome" economy and the "austerity" conditions existing elsewhere in the world.

I think it must be obvious to all that our pollution problem is not going to be solved overnight. Ninety percent of the 35 or more states in which there are large populations and/or heavy concentrations of industry have what are generally considered adequate stream-pollution laws, and the agencies enforcing these laws are doing a commendable job in the face of the difficulties that confront them. When Congress adjourned in July, it had pending a half dozen or so bills relating to stream pollution. A simple process of interdiction is not alone, however, going to be effective. The matter is not that simple.

Broad problems of equity must be considered; municipalities must raise funds to build treatment plants even though taxpayers are already uttering plaintive cries of distress as they scan their 1947 tax bills and despite the fact that in many states municipal budgets have reached the statutory limit provided by law. Methods and techniques for treating industrial wastes will, in many cases, have to be developed in the laboratory and then through a tedious process of pilot-plant adaptation be made available for practical application. All this is going to take time. It is our business to know what other industries are doing about their pollution-abatement problems and I know that most of the industries I have mentioned are carrying out comprehensive and well planned abatement programs. I have told you in detail what the pulp, paper and paperboard industry is doing and I can assure you that this industry will meet its responsibilities.

MR. WILSON: How does the progress in dealing with paper-mill waste in America compare with progress in Europe, and are the methods in use in Europe at variance with those employed in American industry?

MR. WINGET: Dr. Harry Gehm, our technical director, will be able to answer the question.

DR. GEHM: Shortly after the war, with the cooperation of the Army, the pulp and paper industry, with a number of others, sent a corps of experts to Europe to review their progress along manufacturing and other lines, including waste utilization and treatment and stream-pollution reduction. In general the findings may be summed up by saying that in this country development work is far ahead of European techniques. In Europe there are or have been a few utilization procedures which have not been employed in this country. Our failure to use them is due to the difference in economies. During the war Germany was pressed for materials and for foodstuffs; therefore certain adhesives, for example, were developed from paper-mill wastes and used by both the army and civilians. The quantity of these materials we found was extremely small, and the quality was definitely *Ersatz*—poor substitutes for materials which were plentiful in this country.

There has been some production there of fodder yeast, which as Mr. Winget told you we are investigating at the present time. This material has a great number of drawbacks from our standpoint, in production, in production cost, and in competition —competition being not from the point of view of making profit but in keeping the yeast plant operating. If we went into large-scale production the plant might run a couple of years and then be closed down by the competition of soy-bean meal or other materials. Again, we found that the quantity produced in all Germany was equivalent to that which could be produced here by a single mill.

In Sweden there have been in development for a number of years processes involving the burning and chemical recovery of certain wastes. Careful investigation of these processes has led to the conclusion that they have never been perfected to the point that they would be continuous—that is, so that they could be depended on to operate day in and day out as the mill does.

A word about advancement in this country. I may say that we have developed, particularly in connection with the sulphite industry, a process that we hope and believe will be successful for burning the waste and eliminating its discharge into the stream. Now, this process is so promising that one company succeeded in securing financial backing to the extent of nearly $10,000,000 for the building of a full-scale unit. However, a process of this type is applicable only in large mills, so we must continue our search for methods which will apply to the smaller operations.

MR. WILSON: To what extent are any of these methods controlled by patents which would restrict their use?

DR. GEHM: Burning processes are very generally patented. However they are readily available because the patentees, generally equipment suppliers, are anxious to promote their processes. In connection with our abatement and treatment methods we hold patents only for our protection—that is, to allow free use without interference. We are perfectly free in disclosing all our processes, not only to our own industry but to any other industry or anyone else who is interested in applying them.

MR. KENNETH REID: I know of one patent that is held by a paper mill, namely Marathon at Rothschild, Wisconsin. It is a satisfactory process of treating the waste, and at a profit. On inquiry the patent owners said they didn't want other mills to use it. I asked why, and the reply was: "Well, simply because in respect to our principal product, vanilin, from which vanilla extract is made we supply two-thirds of the United States demand from this one mill. If all paper mills installed this process there would be enough vanilin to float the U. S. Navy and the treatment process would be a source of expense rather than of profit."

I think that example illustrates the situation in the treatment of industrial waste. The industry naturally looks upon an investment in treatment plant in the same light that it looks upon any investment in plant extension for increased production of its regular product. Unless it can show a comparable profit on the treatment process it quite naturally, from a business standpoint, considers it economically unfeasible. I think that the pulp and paper industry knows how to treat its waste so as to make a satisfactory and very large reduction in the polluting character of its effluent. The whole problem is one of economics. If all mills used a process the by-products would flood the market, the price would go down and the operation would be vastly more expensive than it is when just one mill uses it.

One other example—the Puget Sound Pulp and Timber Company during the war, after a hard struggle to get permission from WPB, manufactured alcohol. Thus they came in competition with farm products; the farm interests did not want the paper mills to get into the alcohol business. I think it should be made clear that the research that is being carried out now is largely a matter of placing treatment processes on a profitable basis, that it is economics rather than lack of technical knowledge that holds back the treatment of waste.

Mr. Winget: I do not think the pulp and paper industry knows how to treat waste sulphite liquor at any expense except one which would be considered prohibitive. Of course, you could treat waste sulphite liquor or any other waste by methods which would entail tremendous cost for fuel. But, as you have pointed out, the paper mills are in business to make money, and in order to finance a plant to treat any of these wastes they have to go to their bankers to get money. However, I think they attach less importance to financial considerations than you assume. Many paper companies are applying waste-treatment methods at considerable loss. It is our belief that the paper industry is never going to make any money out of waste material.

OUR WATER POLLUTION ABATEMENT PROBLEMS

C. T. Wright
U. S. Public Health Service

Since streams, lakes, and tidal waters are among our most important natural resources, a brief discussion of our pollution-abatement problems should be of interest to all conservationists. This problem is vital to the conservation of fish and wildlife. I have been interested in the problem of water-pollution abatement for many years, because, in my opinion, this is one of the major unsolved public health problems in many parts of the country, especially the Rocky Mountain area where irrigation is so essential to agricultural interests.

During the early development of our communities, the disposal of sanitary wastes became a serious problem which was solved only after public water supplies were developed, thus making the construction of modern water-carriage systems of sewage disposal possible. Where public sewer systems have been installed, there has been a marked reduction of water-borne and fly-borne diseases. Although the installation of sewer systems solved a number of local public health problems, the discharge of untreated wastes into our streams, lakes, and coastal waters creates a problem of far-reaching significance that can be solved only through combined

efforts of our communities, states, and federal agencies.

The rapid increase in population and the enormous expansion of industries in the last generation have resulted in increased volumes of sewage and industrial wastes in our watercourses. The rapid expansion during this period has been responsible for the serious pollution of streams in the more populous sections of the country. Although a large number of communities have provided sewage-disposal plants for the treatment of wastes, such installations have not kept pace with the growth of population.

Effects of Stream Pollution

From a public health and conservationist's point of view, the major effects of stream pollution by sewage and industrial wastes may be summed up under the following headings:

1. Damage to water supplies that are used for public and industrial purposes.
2. Detrimental effects in uses of streams for agricultural interests, especially the pollution of water used for irrigation purposes and watering stock.
3. Destruction of fish and other natural aquatic life, through suffocation and introduction of toxic substances into streams.
4. Injury to property values, through the creation of nuisance conditions offensive to riparian dwellers.
5. Damage to streams for recreational purposes, such as fishing, boating, and bathing.
6. Detrimental effects on uses of streams for navigation and power.

I would like to elaborate briefly on some of the more important water uses to illustrate conditions that have been created by stream pollution.

One of the outstanding features of American water-works practice is the extensive use made of streams and lakes as sources of public water supply. About two-thirds of our population is served by surface water supplies, and as population increases more dependence will have to be placed on streams and lakes as the only sources able to meet the demands. Ground water supplies are diminishing in most areas.

During the past two decades a steady reduction has taken place in the incidence of typhoid fever and other water-borne diseases throughout the country, especially in urban communities where practically all surface water for domestic purposes is purified. Regardless of this trend, pollution of the sources of many surface supplies has increased so rapidly in the densely populated areas, that questions have arisen as to the possibility of a failure of existing safeguards to provide an adequate degree of protection.

Although water-borne typhoid has been virtually eliminated in most communities by purification of the drinking water, the incidence of water-borne diarrhea and enteritis remains high. It is evident, therefore, that stream pollution by domestic sewage continues to present a definite hazard to public health.

We are particularly concerned in the Rocky Mountain area about the use of polluted water for the irrigation of food crops. I believe this practice is partially responsible for the high incidence of intestinal diseases in this area during the summer months. Since infectious diseases of the intestinal tract, such as typhoid fever, cholera, and the dysenteries, are carried in polluted water, the use of this material for the irrigation of vegetables is most dangerous. Reliable reports reveal that the "polio" virus has been isolated from sewage and from the final effluent of sewage-disposal plants. The significance of these discoveries is somewhat uncertain at this time. Further study and research are needed to determine the role of polluted water in the transmission of poliomyelitus.

The standards of water quality vary according to the degree of protection needed for public health purposes and for conservation, so I will discuss requirements and some common laboratory tests used to determine the quality of water. The behavior of water courses subject to pollution and the quality of the waters have been studied extensively in Europe and in the United States. As a result, desirable characteristics of stream quality pertinent to specific water uses have been established.

The objective of pollution-control activities is the regulation of waste disposal into public waters, so that standards of water quality may be maintained which are compatible with stream use in specific localities and the greatest possible yield to public interests.

Undesirable bacterial contamination of streams is the most widespread effect of pollution. The extent of this pollution is determined by what public health workers call the coliform bacteria counts. Bacteria of the coliform group are normal inhabitants of the intestinal tract of warm-blooded animals, including man, and are abundant in domestic sewage. The number of coliform bacteria in stream water is used as an index of sewage pollution. Although the coliform bacteria are used as an index of general sanitary conditions in natural bodies of water polluted by sewage, their more important applications are in judging the sanitary fitness of water supplies for domestic, industrial, and irrigation uses, and for shellfish propagation and bathing purposes. Limiting densities of coliform bacteria have been established for waters that are used for drinking purposes, bathing, and shellfish propagation. These standards are valuable to the engineer because they furnish him with the data required to determine the degree of treatment to be provided for both water and sewage works.

In unpolluted streams dissolved oxygen, which is essential to fish and aquatic life, tends to remain at or near the saturation level. In polluted streams, it is depressed by the oxidation of domestic and industrial wastes that are discharged into the water. The minimum oxygen requirements for streams are dependent on the particular uses to which they are devoted, although 2 or 3 p.p.m. of oxygen in a stream usually mark the minimum level. Septic conditions and the destruction of fish and aquatic life follow when oxygen levels fall to or near the zero point. For the maintenance

of fish life a minimum of 5 p.p.m. is desirable, and a monthly average of not less than 6.5 p.p.m. of dissolved oxygen should be maintained.

The Process of Natural Purification

The popular belief that streams purify themselves in a relatively few miles below the point of pollution is not true. There are natural processes that lessen impurities in water courses, but the rate of natural purification is dependent on the character of the organic matter, the presence of available oxygen, the rate of aeration, temperature, sedimentation, and the velocity of the stream.

The process of natural or self-purification depends upon biological activity that brings about the decay of the organic materials discharged into the stream. The organic materials in the wastes are utilized as a source of food for organisms of various kinds. As these materials are worked over and utilized by successive groups of organisms as a source of food and energy, they are changed and reduced to simple basic inorganic compounds which are inoffensive. When the organic matter is completely nitrified or oxidized, the oxygen balance in the stream will be re-established. The term "oxygen balance" designates the relation between the oxygen demand by the organic matter of the entering sewage and the available dissolved oxygen in the stream.

At the same time that this oxidation is going on, some of the organic matter is settling as sediment. If oxidation is complete before the matter has settled on the bottom, the result will be an inoffensive silting-up of the river. If oxidation is not complete, however, there will accumulate offensive putrefying sludge banks that will give off offensive gases.

The most important condition for the successful purification of a stream is an initial quantity of dissolved oxygen to oxidize all the organic matter contributed to it, or the addition of sufficient oxygen subsequent to the introduction of sewage to complete the oxidation. Oxygen may be added through dilution received from tributaries, through aeration at falls and rapids, by the action of wind, by absorption from the atmosphere, or through the action of microscopic organisms.

Sewage Treatment

In treating sewage before it is discharged into natural waterways, engineers follow the same principles as are encountered in the natural purification of streams, but the various processes are speeded up materially .

Modern sewage treatment solves the pollution problem by making germ-laden raw sewage unobjectionable. The treatment separates the sewage into two parts, liquid and solid. After adequate treatment the liquid portion can be safely discharged into streams, rivers, and lakes, and after processing the solids can be sold as fertilizer and soil conditioner or disposed of as land fill.

The treatment of sewage is described as primary and secondary treatment, and sometimes final or finishing treatment.

Primary treatment involves screening and sedimentation. Its purpose is the removal of the larger debris, especially the floating objects and of material capable of settling and forming objectionable sludge deposits. Primary treatment, with or without subsequent disinfection with chlorine, may be quite adequate if the receiving stream provides sufficient dilution for ultimate disposal without nuisance.

Where stream capacity is limited, secondary treatment in the form of some oxidation process is given. This may be by disposal on land, sand filtration, or treatment in a trickling filter or activated-sludge plant.

Where a high degree of bacterial removal is required, additional final treatment is sometimes given the effluent. This process may involve the use of secondary sand filtration or the chlorination of the effluent from either the primary or secondary process.

Physical and economic considerations are such that the complete elimination of wastes from streams is impossible. It is obvious that the most effective social and economic use of public waters would not accrue if vital domestic and industrial activities were unduly curtailed by arbitrarily restricting the waste-disposal use of streams in favor of other uses, such as recreation.

Administration of Pollution Abatement

The general magnitude and importance of the water-pollution problem in the United States, and its relation to the various uses of water and to the public health have been well established. Likewise, the inability of state and local authorities adequately to control the pollution of interstate waters without the assistance of a central coordinating agency has been demonstrated over the years.

Responsibility for stream-pollution abatement is primarily local. Power to require its abatement rests with the local communities and the states. The federal government has little authority in this field. All of the states have adopted laws of some kind for the purpose of controlling pollution. Because the problem is technical and one requiring constant attention, the states have delegated administration of the laws to some state agency, usually the health department, since the protection of public health is usually the primary purpose of pollution abatement.

The state agency having jurisdiction should be adequately staffed and financed to carry on an effective educational and promotional program and to conduct fact-finding investigations relative to pollution.

Many communities and industries are indifferent to the pollution they contribute to streams, and as a result, pollution abatement is often given little consideration in their improvement programs. The local health authorities have not always been successful in solving this problem because some of the states lack suitable legislation, funds, and personnel to carry on an effective program for the abatement of water pollution.

Since about 1936, a great deal of interest has been shown by various groups, including most of the health authorities and conservationists, in

promoting some form of federal stream-pollution legislation to aid in correcting existing conditions. It is generally agreed that federal participation in pollution abatement should take the general form of establishing a central technical agency to assist the states in promoting and coordinating education, research, and enforcement.

One or more bills have been introduced in Congress each year since 1936 and they have all failed of passage for various reasons. However, present trends indicate that some form of federal legislation for the control of water pollution may soon be passed.

Conclusions

Although a great deal of progress has been made in solving stream-pollution problems, we are not making the progress that is considered necessary by public health authorities and conservationists. It is generally recognized that there is a need for federal legislation to stimulate activities in the abatement of water pollution and provide the necessary coordination of education, research, and enforcement.

Regardless of how a pollution-abatement program is started, two steps are essential if ultimate success is to be attained. First, the facts must be determined and second, the public must be made conscious of the problem and of their own responsibility. In a municipality, failure to advise the public will result almost invariably in the defeat of a bond issue for sewage-treatment works. An intensive campaign of public education has been generally effective in stimulating action on the part of municipal officials in eliminating stream pollution. All conservationists and public health workers should take an active part in calling the water-pollution problem to the attention of the public.

Mr. Hogan: The next speaker will be Dr. Gabrielson, President of the Wildlife Management Institute, who will deal with the problems confronting our wildlife in connection with flood control, pollution, and related matters.

CONSERVATION OF OUR PUBLIC WATERS

Ira N. Gabrielson
President, Wildlife Management Institute

The preceding speakers have outlined philosophies and programs affecting the public waters of this country. It is significant evidence of public understanding of the biological value of water that three speakers, representing the Army Engineers, the pulp and paper industry and the Public Health Service, have appeared before this group. It is to be regretted that the Reclamation Service was not also represented for there would have been before you at one time representatives of the agencies that have in the past done the most to injure the biological productivity of water. They also represent the groups that have the greatest opportunity to conserve these values—if they choose to take advantage of that opportunity.

There are now laws, particularly the strengthened Coordination Act, sponsored by Representative Robertson of Virginia and Senator Cordon of Oregon, that provide both the opportunity and the responsibility to consider these values in planning future use of our public waters. The presence of representatives at this meeting is only one of the numerous evidences of a desire on the part of the responsible heads of these groups to accept the opportunity.

In the past, fish and wildlife, along with other renewable resources, have suffered much damage by flood control, stream straightening, disposal of industrial wastes, and irrigation and power developments. Some of this undoubtedly could have been prevented, if proper consideration had been given to the biological problems during the planning stage of the programs. This loss was partially due to the failure of those interested in these resources to present their value forcefully enough. Yet this failure does not excuse the negligence of responsible public officials who should have considered all public values in planning and carrying out operations of such magnitude.

It might be well to outline a few basic facts that should be considered in planning any operation affecting our rivers and streams.

First.—All natural waters are biologically productive. They can produce fish, shellfish, fur animals, and waterfowl in varying quantities according to the character of the water itself, the fertility of the land in the stream beds and lake bottoms, and the climatic conditions that exist from year to year. Often an acre of water is as productive as an acre of adjoining agricultural land. In many instances, it yields a greater *net* economic return than the same type of land does when drained and put into intensive agricultural use.

Water courses, lakes, swamps, marsh lands, and overflow lands in stream bottoms are not wastelands simply because they are not plowed, harrowed, and planted. These types of habitat can produce in abundance fish, fur, and waterfowl, all of which have a high economic value under present-day conditions. The value may run into huge figures as in the case of the Columbia River salmon run, or it may be more modest as in the Illinois River fisheries. The overflow lands of the lower Mississippi, for example, produced one of the finest forests to be found in America. They would still be producing those forests and acting as natural expansion areas for flood waters, if man had not interfered.

These statements could, if time permitted, be further emphasized by many examples. It is these and related values that should be considered before anything is done to impair or destroy natural productivity. Conservationists sincerely believe that many past projects would never have been undertaken if there had been a careful balancing of existing values against the alleged benefits. They believe that many other projects would have been greatly modified if due consideration had been given to all values.

Second.—Any alteration in the level of a lake, or in the existing gradient and flow of a stream affects its biological productivity either favorably or unfavorably. The effect may be great or little—depending to some extent on the character of the alteration and the management of the water following the change. For example, a wildly fluctuating water level in an impoundment, whether it be in a lake whose level has been raised or a stream that has been dammed, greatly increases the difficulty—if it does not render completely impossible any substantial production of fish and wildlife. The area between the high and low levels is likely to be almost entirely sterile from a biological standpoint. Another example—stream-straightening operations, whatever their purpose, increase current and often destroy, by scouring action, spawning beds and living habitat for valuable fish. They may also have other bad effects.

Therefore, consideration should be given to the results of such operations and plans made to minimize any evil effects, wherever possible. In fact, it would be sound public action to use every effort in such programs not only to reduce damages to wildlife values, but to add to them wherever possible.

Third.—Pollution that interferes with biological productivity does not necessarily coincide with pollution that is bad from a public health standpoint. The two are not synonymous. Domestic sewage that may be objectionable from a public health viewpoint actually may be of some value as fertilizer by biological standards. Only when the stream is overloaded with this type of pollution does it become certainly destructive. On the other hand, some industrial wastes may be deadly to living organisms while they are still present in such minute quantities as to be of little importance as public health problems. In this connection, emphasis should be placed on the fact that pollution sufficient to result in a spectacular destruction of fish life is not the only way in which water can be rendered sterile. Much smaller quantities of some pollutants will destroy the microscopic life on which the fish ultimately depend and thus ruin the productivity of the water as effectually as the more spectacular direct loss of fish.

Fourth.—Wildlife and fish are public resources. They belong by law to the state as an agency of the people. As a public resource, they should, in planning the expenditure of public funds for the alteration or manipulation of public waters, always be given consideration ahead of enhanced values to private interests. As an example of past failure to follow this principle, there is the history of the lower Mississippi and its tributaries. Here, the levee system, designed ostensibly for flood control has crept closer and closer to the low water beds of these streams. Incidentally, they have at public expense reclaimed much private land and protected it from overflow at an annually increased public maintenance cost. This has apparently been done not only without considering the flood-control value of the overflow lands, but without considering the forest-production values or the value of the publicly owned fish and wildlife annually produced.

Fifth.—Pollution to the point of destroying these public values should

have no place in our waters. It does exist in many waters today, but that is no justification either for its continued existence or for the introduction of new pollution into the waters in the future. Much of the existing pollution grew slowly as communities and industries expanded and became destructive before there was much awareness of its evil effects. Ignorance may have been an excuse at one time, but it does not suffice. The pulp and paper industry, represented here today, is not the only industry that creates pollution, but it is one that is making definite efforts to find ways and means of solving the problems created by its waste products. It should be given great credit for the efforts; yet the industry-sponsored research program should not blind us to the fact that it is still creating new problems in new areas. One recently came to my attention. In this case, a paper company located a mill on a stream that was entirely too small to absorb its wastes without destroying its fish and other wildlife. This state happened to have a fairly good pollution law and the company involved was warned of the consequences. It built the plant nevertheless, depending on political pressure (so far successful) to prevent the responsible state officials from taking action. In this particular case, two honest officials resigned from the pollution-control board when their efforts to bring the case into court was blocked by political pressure applied above them. As long as members of this or any other industry resort to this type of chicanery and calculated chance in violations of pollution laws, they should be and can expect to be looked upon with suspicion by law-abiding citizens.

Sixth.—The flush production of fish that usually follows any impoundment of water, whether for irrigation, navigation, power, or flood control, should blind neither the public nor the planning officials to the fact that such production is almost invariably a temporary phenomenon that is followed by a great decline in fish populations and their eventual stabilization at levels far below the normal production that should be obtained from the area of water involved.

The long continued productivity of the TVA lakes is being used as an example of a successful program in meeting this problem. Everyone sincerely hopes the optimism is justified. Yet, there are signs that the program of management involved has only delayed the inevitable decline. If it has, it means real progress, but there are as yet few projects that could be handled and managed as has been this series of impoundments. Consequently, it would at present be impossible to duplicate the water-management program on any other river.

Seventh.—Impoundments, even when relatively productive of fish life, usually produce fish of much less value gastronomically and as a sporting recreation. The volume in pounds produced in a river impoundment may be much greater than in the river, but carp, suckers, buffalo, and other less valuable fish often provide a much greater proportion of the total than in the original stream. Any statistics of production in an impound-

ment must be examined in the light of this fact to get a true picture of the relative values of the production before and after impoundment.

Eighth.—Where a swamp or marsh is destroyed by drainage or by flooding to a greater depth, the value of the fish, fur, waterfowl, and all other resources should be considered in judging the potential benefits from the project. Furthermore, it should be considered on the same basis. Too often evaluation is made on the basis of the annual production and then offset by the capitalized value of the land to be irrigated, the power to be produced, or industries to be attracted by the proposed development. Both should be evaluated on the same basis and the project built with public funds only when the total cost of construction (not preliminary estimates of cost and operation) and the loss from deterioration or disappearance of other resources are clearly and certainly overbalanced by the new public values to be secured.

These are the more obvious basic ideas that should enter into these problems. Many others of less general nature could be listed. The construction agencies are showing a willingness to consider the wildlife values in planning future projects. What are conservationists going to do to get the most out of this new legislation?

First.—The state conservation departments and the Fish and Wildlife Service can provide adequate technical staffs to do the great mass of detailed work involved in studying the effects on fish and wildlife of proposed developments and of finding methods to lessen the ill effects of such projects so far as possible.

Second.—All conservation agencies can stand firmly together on the proposition that where outstanding wildlife resources are destroyed or seriously impaired similar resources of equal value be provided at the expense of the engineering projects. These projects bear the cost of moving and relocating roads, railroads, and telephone lines. Wildlife is a public resource, and if the project is worth constructing, it can and should pay for replacing wildlife refuges, wildlife-production habitat, fish-spawning areas, fish hatcheries, and game farms.

Third.—There can be a concerted program to educate the local field men of the construction agencies as to the possibilities of saving or even improving these values. Even though there is every disposition on the part of policy-making officials to solve these problems, 100-percent cooperation in planning the projects will not be secured until the field men who make the preliminary plans are equally cooperative. They must have adequate information which only conservation agencies can supply.

Fourth.—Conservation agencies can unite to fight particularly destructive projects, no matter where located or who the sponsors may be. The proposed destruction of the Putney Slough waterfowl area in South Dakota by the Army Engineers is an example.

Fifth.—Conservation agencies should push with the utmost rapidity, research projects designed to give more accurate techniques than those now

used in appraising these projects, and also institute research projects to give a broader basis of knowledge on which to base these appraisals.

In conclusion, significant progress has been made in recent years in solving some of the problems brought upon us by a constantly expanding civilization. I hope that all agencies may work in earnest cooperation until some day in the not-too-distant future some conservationist may stand before this group and make a report of splendid accomplishments in meeting the opportunity open to us.

Part III

Business Sessions

AMERICAN FISHERIES SOCIETY

Seventy-Seventh Annual Meeting

The seventy-seventh annual meeting of the Society was opened in the Cosmopolitan Hotel, Denver, Colorado, at 10:00 a.m., Wednesday, September 10, 1947. The agenda were as follows:

Wednesday, September 10

Morning: Joint meeting with the International Association of Game, Fish and Conservation Commissioners.

Afternoon: Open for committee meetings and conferences.

Evening: Annual banquet—Silver Glade Room.

Thursday, September 11

Morning: Opening remarks of the President; appointment of sessional committees; reports of officers, standing committees, and special committees.

Afternoon: Presentation and discussion of papers.

Friday, September 12

Morning: Presentation and discussion of papers.

Afternoon: Presentation and discussion of papers; reports of sessional committees; election of officers and installation of the new President; concluding business.

Saturday and Sunday, September 13 and 14

Tour of scenic areas of central Colorado under auspices of Colorado Game and Fish Department.

OPENING REMARKS OF THE PRESIDENT

Joe Hogan

In making the trip from Arkansas to Colorado we traveled a section of the country that brings forcibly to mind the importance of water conservation as related to fishery work. The past quarter of a century has provided one important lesson we should have learned—namely, that we must protect our native fish habitats if we are to remain in the business of producing fish for food and recreation, for the present generation and for those to come.

We like to think that our streams are a capital investment to which we can repair on special occasions and clip dividend coupons by catching some fish or spending a few pleasant hours along the water's edge. We would like to think that each stream will provide good fishing forever. But this is not so. Biotic conditions in our waters are gradually changing as time passes. As a rule only little changes are seen as the years come and go, but over a long period of time profound changes occur. Varying stream flows, increased fishing pressure, pollution, higher turbidity, and other man-made alterations are hastening the trend toward lower fish-carrying capacities.

The American Fisheries Society has in the past devoted many pages in its Transactions to the relative merits of stocking fry or fingerlings, spring stocking versus fall stocking, stocking versus no stocking at all, seasons, legal length limits, creel limits, mesh of commercial gear . . . . Many hours have been spent in discussion of life histories of fish and on important phases of artificial propagation. The lesson that we should have learned from these studies is that each species of fish occupies a certain place in a given habitat, and that nothing we can do will alter the instincts or specialized requirements possessed by this fish. If we alter waters to such an extent that certain natural habitat factors are eliminated, we also eliminate any fish requiring those factors. Examples are the west coast salmon, the trout in waters that have been impounded, and the smallmouth black bass waters that no longer exist because of stream alterations.

We must take steps to preserve our natural fishery habitat; we must improve and expand our fishing waters if we are to meet the challenge that will come in the near future. Imprudent land use is largely responsible for the conditions that now call for flood control. Loss of basic fertility and heavy fishing pressure are factors that are largely responsible for the decline in fish production. If we are to meet the demands of the increased number of fishermen we must expand our present fish-producing waters by creating impoundments in areas where lakes or running streams do not now exist. We cannot hope to hold the forest primeval and keep the fields and streams as our ancestors knew them. The crossroads store is now a thriving city; the sawmill that once employed a few men is now developed

into a pulp and paper industry employing several thousand persons; and where small fields once were cultivated our national economy now is based upon plowing every foot of soil that is tillable. Nothing can add more beauty to a city than a clean stream flowing through its limits; but nothing can be more disgusting than a stream that has become an open sewer. Industry should be encouraged to prosper and expand so long as it operates according to the golden rule.

We in the American Fisheries Society should bring into our meetings all who are interested in the many and varied fishery fields, and we would be at fault if we did not attempt also to expand our Society's circle of influence outside the fishery fields to include all persons who are interested in or who make a living by following a trade that ultimately has an association with the basic factors of fish production. The farmer who tills the soil along the stream banks and who has a fish pond should be a member of our association. The engineer charged with flood control on our public waters, who builds dams and levees, and who snaglines our streams should be encouraged to become a member of the Society. The industrialist who uses large amounts of clean water in the manufacture of goods and who also seeks a stream to unload waste materials should know what damage he is doing in the streams and should be a member of our Society.

The efforts of our membership in artificial propagation of fish have given good results in years past. Law enforcement is necessary to a certain point in the preservation of fish stocks. To balance our efforts and get results I believe we now are in need of an expansion of fish-management policies and of our sphere of influence to include all persons who come in contact with our fish-producing waters or with the factors that influence them. The Society was truly organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fishery problems.

APPOINTMENT OF SESSIONAL COMMITTEES

Time and Place

Lester Bagley, Wyoming, *Chairman*
Clarence Cottam, Illinois
G. W. Davis, Vermont
Willis King, North Carolina
Oliver R. Kingsbury, New York

Auditing

James N. Gowanloch, Louisiana, *Chairman*
W. C. Beckman, Michigan
Marion Toole, Texas

Resolutions

Paul Needham, Oregon, *Chairman*
Arthur W. Hare, Pennsylvania
Douglas Omand, Ontario
E. B. Speaker, Iowa
Fred Thompson, New Mexico

Nominations

M. C. James, D. C., *Chairman*
G. W. Malaher, Manitoba
James R. Simon, Wyoming
W. C. Senning, New York
C. M. Mottley, D. C.

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

Russell P. Hunter

The Treasurer's report for the period July 1, 1946, to June 30, 1947, shows a favorable balance at the present time in both the general fund and the permanent fund.

There are three volumes of the Transactions in the process of publication at the present time—those for the years 1944, 1945, and 1946. Printing and other expenses of preparation of these volumes may draw down our general fund to zero. I feel that it is advisable to ask for authorization to draw upon our permanent fund if necessary to meet publication expenses.

A budget of $5,802.00 was authorized by the Society last year. The largest item in this budget was $4,400.00 for printing. Only one volume was published instead of the two we anticipated. It will be necessary to budget for the printing of three volumes this year.

The last bills sent out were for the year 1946–1947. Dues for the year 1947–1948 are now payable but I would prefer not to render the bills to the members until at least one volume of those in process has been delivered to the membership.

Membership Report

Class of Membership	*1945–1946*	*1946–1947*
Active	428	653
Club	21	21
Life	43	27
Library	47	47
Honorary	7	6
State	29	33

List of Active Members by States

Alabama	7	Idaho	6
Arizona	2	Illinois	27
Arkansas	6	Indiana	7
California	57	Iowa	7
Colorado	8	Kansas	0
Connecticut	9	Kentucky	3
Delaware	0	Louisiana	7
District of Columbia	25	Maine	5
Florida	3	Maryland	11
Georgia	6	Massachusetts	15

Michigan	51	Oregon	29
Minnesota	29	Pennsylvania	22
Mississippi	1	Rhode Island	3
Missouri	12	South Carolina	1
Montana	8	South Dakota	0
Nebraska	10	Tennessee	9
Nevada	3	Texas	6
New Hampshire	2	Utah	4
New Jersey	6	Vermont	2
New Mexico	7	Virginia	6
New York	47	Washington	31
North Carolina	4	West Virginia	6
North Dakota	1	Wisconsin	33
Ohio	19	Wyoming	11
Oklahoma	7		
Total for United States			581
Outside of United States			72
Grand total			653

REPORT OF THE LIBRARIAN

KENNETH E. COBB [1]

Back volumes of the TRANSACTIONS are currently available as follows and in the quantities stated:

Year	*Quantity*	*Year*	*Quantity*
1897	10	1925	219
1898	10	1926	85
1904	1	1927	172
1906	75	1928	88
1907	82	1929	89
1908	80	1930	80
1909	58	1931	105
1910	55	1932	82
1911	34	1933	31
1912	102	1934	18
1913	130	1935	19
1917	21	1941	22
1919	99	1942	107
1920	87	1943	77
1921	34	Index (1872–1928):	
1922	21	Cloth bound	544
1923	21	Paper bound	167
1924	135		

[1] In Mr. Cobb's absence, the Report of the Librarian was presented by R. P. Hunter.

There is a demand for volumes for the years 1936, 1937, 1938, 1939, and 1940. I believe it would be well for the Society to purchase any extra volumes for these years from our members. Although the resale of the volumes would not bring in profit it would assist some libraries and individuals to make their files more nearly complete.

REPORT OF DIVISION OF FISH CULTURE

O. Lloyd Meehean

As the years advance it becomes more evident that fish culture is undergoing a metamorphosis. The current emphasis on fishery management requires the hatchery operator to be responsible for his fish until they reach the creel. Before the beginning of the previous decade, fish-culturists in general were content to rear their fish and stock the streams in accordance with local pressure and requests. It is not at all strange, in the light of our present-day knowledge, that the conscientious efforts of the fish-culturist did not always pay dividends. We can see now that promiscuous stocking was only a stop-gap measure. The fishermen are demanding more for their money and, generally speaking, they have succeeded in gaining attention and in some instances results. Stream and lake studies, as well as research on various related problems, have been conducted by biologists, although the funds and personnel generally have been inadequate for the job. It has been found that streams and lakes are very similar to pastures in that they will support fish in proportion to the food supply when other factors are favorable. Consequently every stream and body of water must be inventoried and a stocking policy determined to use its food supply adequately and at the same time provide as much fishing as possible. This program is more than many states and agencies can afford: yet with the funds available considerable progress has been made. At least the major "pilot" experiments have been completed but at the same time the list of unsolved problems in fishery management has been multiplied many times.

As a result of the technical studies, it is becoming more and more clear that the fish-culturist must recognize the importance of proper stocking policies and must adjust his production in accordance with the requirements of the bodies of water to be stocked. He must become more active in management work, and where his talents permit he will need to check stocking policies for soundness and recommend modifications as necessary.

The changes in duties and responsibilities of the fish-culturist are only part of his problems. Emphasis on the stocking of legal-sized trout is increasing constantly because of the increased fishing pressure in localized areas (the word "localized" should be interpreted in line with present-day modes of travel). Many trout hatcheries were not designed for the rearing of large fingerlings and yearling fish. In the early years, and unfortunately at some places today a trickle of ice-water plus political pressure was all that was needed to obtain inadequate funds for an unneeded hatchery.

This situation has led and will continue to lead to the closure of undesirable units as well as to costly rehabilitation programs. Modern trout-hatchery design calls for large flows of water at good growing temperatures, and adequate facilities for the preparation and storage of food, a well-equipped shop, garage space, residences, and power tools and equipment.

The days of collecting wild eggs with the subsequent hatching, rearing, and stocking of small fingerlings are gone. Trout culturists must be schooled in the science of fish husbandry. They must have a working knowledge of fishery management, nutrition, and physiological requirements of fishes. Hatchery management should be a basic part of their training.

The transition for warm-water fish culture is even more pronounced than with the culture of trout. In general, the production of fish is now distributed in barren or new waters, while established waters receive fish for corrective stocking only. Where warm-water species are already present, natural spawning is believed generally to be adequate granted that suitable spawning areas and a proper balance of forage and game species exist. Corrective stocking of such waters follows an examination which indicates improper balance between predatory and non-predatory species. Haphazard stocking may cause more harm than good. It is imperative that the requirements of the waters be determined if the best use is to be made of the water to provide adequate fishing.

The construction of thousands of farm ponds has placed a great burden on fish culture. Hatchery production schedules have been changed to meet the stocking requirements. Although the bass-bluegill combination is the most popular, in many areas of the country these species are not producing the desired results. Black bass alone or in combination with other species offer encouraging possibilities. Fertilization of farm ponds will increase the production of fish, although too little is known about the use of fertilizers in waters of different chemical content. The poor production or complete failure of many farm ponds is the result of inadequate fishing or unfamiliarity with the basic principles of management. Dense populations of stunted fish result from insufficient food and space and improper balance of a mixed population is easily caused by selective fishing. The success of farm ponds depends upon the application of good management principles in stocking, fertilization, and harvest. Every hatchery worker must be well schooled in the management of these fishing waters. The farm-pond program will be successful only in proportion to our ability to educate the pond owners. A tremendous responsibility is placed on the hatchery superintendent, who is the one in closest contact with them.

The culture of commercial species, especially marine fish and lobsters, has been affected least by the recent change in perspective. The reason, no doubt, lies in our ignorance of the stocking requirements for these species. The value of our propagation activities with commercial species is largely unknown and the wisdom of their continuance has been ques-

tioned. No time should be lost in determining the value and need of this work. The propagation of marine species and lobsters is expensive. If it has no value the funds could be used advantageously for other purposes.

The propagation of commercial species of the Great Lakes has become unimportant except for lake trout. An experiment is in progress at the present time to determine the value of planting of that species.

The value of salmon culture for restoring and maintaining the runs in the Columbia, Sacramento, and other coastal rivers, is not questioned by fishery workers. In order to be assured of returns it has been necessary, however, to rear the salmon to large fingerling size before liberation. Since many hatcheries were designed for handling only eggs and fry, it has been necessary to undertake rehabilitation and expensive programs and provide adequate rearing facilities. Although these projects are costly, the problems they offer are minor compared to the task of integrating the fishery program with those of power, irrigation, flood control, and navigation. Only those agencies directly concerned can appreciate the difficulties involved and the fight that is required to preserve this great fishery. Our experience has proved that good returns can be obtained only from healthy fish. Again, this means good basic training in all phases of operation for hatchery personnel.

Too little attention is being given to the use of modern construction design and of power equipment in fish-cultural work. Although considerable progress has been made in the problems of nutrition and disease control, little effort has been made to reduce the cost of labor in producing fish. Why, for example, don't we have mechanized meat-cutting and food-preparation facilities? Why don't we design ponds that are more nearly self-cleaning? Labor is the highest single item in the cost of rearing fish and will amount to nearly three-fourths of the total. Fish culture of necessity involves considerable hand labor, but too little effort has been directed toward the development of power tools and equipment.

The value of hatchery-reared fish is measured in terms of the returns to the creel or to the commercial fisherman's net. We need, therefore, in addition to perfecting our stocking policies and management practices, to man our hatcheries with staffs of well trained personnel and to improve methods of fish husbandry in order to assure the greatest returns. The need for continuing research programs on hatchery management cannot be overemphasized.

It is believed that fishery administrators should give more thought to their research programs. In comparison with industry and with other phases of animal husbandry, the proportion of funds used for research in fisheries is small. The restriction on funds for this purpose is, of course, reflected in production at the hatcheries in both quantity and quality of fish produced, and later in returns to the fisherman. We are at the threshold of great discoveries in the field of fishery management if we do not neglect research.

REPORT OF DIVISION OF AQUATIC BIOLOGY AND PHYSICS

EDWARD SCHNEBERGER

In compiling the report for the Division of Aquatic Biology and Physics I have attempted to assemble data on fishery research as it applies to fish management. I wrote to a number of people on this matter and received splendid cooperation for which I express my thanks.

It is a pleasure to note that although many research projects did suffer during the war every effort was made to maintain research during that difficult period. Since the close of the war research has again come to the foreground as a necessary tool of management. Research is being employed more and more to determine the causes of poor fishing, and to develop means of improving fishing.

PUBLIC RELATIONS

An item worthy of mention is the educational program that is being carried on by research agencies. This program may be termed "public relations" as most of the agencies are attempting to educate anglers and those associated with fishing to work with the researchers, not against them. It has been learned that proper management of fish cannot be had without full support of all persons concerned. The methods of obtaining the cooperation of the public are quite varied. Popular articles are published in conservation bulletins and sport magazines. Talks are given at conservation-club meetings on local, state, and national levels. Newspaper releases are issued on the same scale. In certain situations sportsmen, or rather leaders of sportsmen's groups, are called in to assist in the planning of projects and often are even assigned duties. This attitude appears to be most healthy. After all, the angler, commercial fisherman, resort owner, boat livery operator, . . . are the people paying the salaries of the researchers and should be in a position to know how and for what their license money is used. Participation in projects also gives the individuals knowledge that the work is being conducted for their benefit and that sound answers to any fish problem take time, money, and reasonable intelligence to obtain. It has been said that persons engaged in conservation work have as much, if not more, of a task in the handling of the public than in the management of fish and game. Through education and cooperation the public can materially assist in bringing about proper management.

MANAGEMENT OF FARM FISH PONDS

A great amount of publicity has been given to farm fish ponds during the past several years. Many popular articles perhaps have overemphasized their ease of management. It is learned, however, that many of the agencies concerned with the management of farm ponds are now attempting to obtain more fundamental data upon which sound management can be based. Further experimentation is being carried on to determine the

effect and usefulness of various fertilizers, both organic and inorganic. Turbidity is an important factor in farm ponds and in Oklahoma, for example, a study is being made to determine the effects of turbidity and to develop methods for its control. Studies of pond basins and surrounding areas are being made to determine the importance of soil in the production of fish-food organisms.

When the management of farm fish ponds first was attempted largemouth black bass and bluegills were believed to be an ideal combination of species for stocking. In many ponds, however, the bluegills were so much more prolific that they soon became predominant, and crowded out the largemouth bass. The end result was a population of stunted bluegills. Farm ponds are now being constructed so that they can be drained easily and the fish population removed. Varied combinations of species and sizes of fish as well as rates of stocking are being tested and considerable emphasis is being given to the use of hybrid sunfish for stocking to prevent overpopulation.

Effects of Year-Round Fishing

The move toward a liberalization of fishing laws to provide for a more adequate harvest was first recommended by TVA investigators when their studies revealed that in many bodies of water anglers did not harvest adequately the available crop of fish. TVA researchers are continuing this work which involves creel-census and population studies and utilizes the cooperation of sportsmen. Similar experiments are being carried on by Michigan and Wisconsin. In Michigan, the non-trout waters in the northern two-thirds of the state have been opened by legislative act to year-round fishing for species not protected by closed seasons. The Department of Conservation has been given authority to remove regulations on the catch of fish in lakes subject to winter kills when tests show a kill to be imminent. In Wisconsin, five lakes have been opened by year-round fishing with size and bag limit removed. The lakes were selected for their variation in size, proximity to each other, and the nature of fish populations present. The program was set up for a 5-year interval in cooperation with local sportsmen's clubs and resort owners. The project is now in its second year of operation. During the first year persons fishing on the lakes were hesitant about taking the smaller sizes of fish, a reaction due primarily to the effects of long periods of enforcement of minimum size limits and, secondarily to a reluctance to keep or include small fish in the creel. Through more publicity and cooperation of local groups, fishing intensity has increased and the second year has witnessed the harvest of more of these smaller fish. Population studies have been made through the use of test-netting and fin-clipping to provide more knowledge of the sizes and numbers of fish. Fishing is under permit. The angler refers his bag for a check by creel-census clerks, who also assist the fishermen by telling them where to fish for a given species and by suggesting the most effective type of fishing.

Cooperative Research

During the past 5 years a number of midwestern states and the U. S. Fish and Wildlife Service have pooled resources for research on problems of mutual interest. Most notable of these projects are: the Upper Mississippi River survey; the Great Lakes lake trout study; the Great Lakes sea lamprey investigations; and the Tri-State Minnow Committee. A brief discussion of activities of each of the groups follows.

Upper Mississippi River Survey.—The Upper Mississippi River Conservation Committee, consisting of representatives of conservation and sanitation agencies of the states of Minnesota, Wisconsin, Iowa, Illinois, Missouri, and of the U. S. Fish and Wildlife Service, was organized in December 1943 for the purpose of conducting a cooperative inter-state study of the fishery resource of the Upper Mississippi River. Later the scope of the project was expanded to include a program for the study of furbearers and waterfowl.

A plan for the investigation of the fishery resource was formulated with the general aim of providing information which can be used as a basis for a sound management program and for uniform regulations on the Upper Mississippi in accordance with biological and economic requirements regardless of political boundaries. Details concerning the organization of the Survey were published in the preceding volume of the Transactions.[1]

Although the analysis of the data collected has not as yet been completed, the Committee has made certain general recommendations governing the harvest of game and commercial fishes. A number of these recommendations have already been incorporated in the fishery codes of the states represented on the committee.

Great Lakes Lake Trout Study.—In December 1943 the Wisconsin Conservation Commission called a conference of states fronting on Lakes Michigan and Superior and representatives of the U. S. Fish and Wildlife Service to discuss the value of the artificial propagation of lake trout for these waters. It was agreed that a cooperative research program should be launched to obtain more facts about the life history and habits of the lake trout and the value of the planting of fingerlings. Fish-culturists, biologists, and administrators at the conference made suggestions as to the nature of the study and contributed toward its inauguration and operation. A technical committee under the chairmanship of Dr. John Van Oosten of the Fish and Wildlife Service drew up plans for a cooperative program embodying the following steps:

1. From 1944 to 1946, rear and plant as many fingerling lake trout as possible, marking at least 10 percent of the number stocked each year by removing different fins.

2. Plant all of the fin-clipped trout in a localized area (Fox Islands) in northern Lake Michigan so as to learn the movements of the fish and to increase the chances of recoveries by the fishermen.

[1] Smith, Lloyd L., Jr., Cooperative fishery survey of the upper Mississippi River. Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 279–282. 1949.

3. Continue the usual egg-collecting methods and fry planting in 1944-1946. Permit no spawn fishing in 1946–1948 for the purpose of rearing either fry or fingerling lake trout for planting in Lake Michigan in 1947–1949.

4. Adopt uniform methods of reporting the commercial catch of lake trout in Lake Michigan.

Michigan and Wisconsin alternated in taking charge of the working program and Michigan was assigned the task of conducting experiments to learn the effects of fin-clipping on growth and mortality and to determine the extent of fin regeneration. Up to the summer of 1947 a total of 411,394 hatchery-reared lake trout has been fin-clipped and planted in Lake Michigan. The states have agreed to pay a reward of $2.00 for each marked fish recovered.

Great Lakes Sea Lamprey Investigations.—The sea lamprey has increased in abundance in the Great Lakes, particularly in Lakes Huron and Michigan, to the extent that it greatly affects the production of major commercial fish species, especially lake trout.

Although the sea lamprey is known to have been present in Lake Erie in 1921, and to have penetrated as far as central Lake Michigan by 1936, only within recent years has it become sufficiently abundant to constitute a major threat to the fishery. This parasite appears to be most abundant in Lake Huron, where there is good reason to believe that sea lampreys were a principal contributing factor in the decline of lake trout production in United States waters from 1,372,000 pounds in 1939 to 38,000 pounds in 1946. Furthermore, lamprey depredations are now reaching critical proportions in Lake Michigan (especially in northern waters), and sea lampreys have been reported from Lake Superior as far west as Isle Royale.

The first prospect for an effective sea lamprey program came in August 1946, when the President signed HJ Res. 366 authorizing appropriations up to a total of $100,000 over a 10-year period for the development of control methods.

In anticipation of federal support, officials of the U. S. Fish and Wildlife Service, the States of Minnesota, Wisconsin, Illinois, Michigan, and New York, and the Province of Ontario formed the Great Lakes Sea Lamprey Committee at a meeting in St. Paul, Minnesota, on September 10, 1946. The permanent organization of the Committee was effected at a second meeting in Ann Arbor on November 14–15, 1946, at which time Dr. Van Oosten was elected chairman. At this second conference a detailed, though necessarily tentative, program was worked out.

As it stands now, the sea lamprey program can be divided into three major phases: (1) the intensive study of the biology and habits of the lamprey with a view toward learning its distribution and abundance and determination of the most vulnerable periods of its life history; (2) the development and testing of devices and techniques for the capture or destruction of adult and larval lampreys; and (3) an investigation of the

effects of the lamprey on the fish and fisheries including data on the frequency of attacks according to species, locality, and season, losses to fishermen through inability to market scarred fish; and evidence on the effects of lampreys on the abundance and production of fish.

The states and Ontario are to be primarily responsible for (1) and (2) above with the U. S. Fish and Wildlife Service acting as a coordinating and advisory agency.[2]

Tri-State Minnow Committee.—During the course of the tri-state fishery conference held in February 1946 representatives of the states of Michigan, Minnesota, and Wisconsin recognized that minnow problems of all three states were similar. To take full advantage of the work being done on this subject by the three states and by the U. S. Fish and Wildlife Service a panel known as the Tri-State Minnow Committee was appointed to coordinate the work. Two members each from Michigan, Minnesota, Wisconsin, and the Fish and Wildlife Service were appointed.

Among the projects undertaken by the states concerned were the construction of a minnow-propagation demonstration area in Wisconsin, propagation of creek chubs in Michigan, and the operation of 26 experimental ponds in Minnesota.

The major project completed thus far by the committee has been the preparation of a publication [3] which attempts to summarize all of the work done in the past on northern bait minnows, as well as hitherto unpublished information furnished by the various states on recent studies.

Annual reports will be made on minnow-culture experiments by each state at the tri-state conference. Material will be published from time to time under the auspices of the Tri-State Minnow Committee.

Control of Aquatic Nuisances

Many states have inaugurated projects to study methods for the control of various types of aquatic nuisances such as algal blooms and excessive growth of rooted aquatic plants. Most of the previous work on this subject has been done in Wisconsin (principally on lakes) and by various fish-cultural agencies (in rearing ponds). The need for control of these nuisances has resulted mainly from increased demands for recreational uses of water for bathing, boating, and swimming. The state of Oregon is now carrying on a project with an appropriation of $25,000 for the control of *Elodea* in a body of water of high recreational value. Their problem is complicated by the fact that great care must be used in the application

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[2] The following publications relevant to the sea lamprey problem appeared in Volume 76 (1946) of the Transactions (published in 1949).

Hile, Ralph. Trends in the lake trout fishery of Lake Huron through 1946. pp. 121–147.

Mackay, H. H., and Earl MacGillivray. Recent investigations on the sea lamprey, *Petromyzon marinus*, in Ontario. pp. 148–159.

Shetter, David S. A brief history of the sea lamprey problem in Michigan waters. pp. 160–176.

[3] Dobie, J. R., O. L. Meehean, and G. N. Washburn. Propagation of minnows and other bait species. Circular 12, U. S. Fish and Wildlife Service, 113 pp. 1948.

of chemicals. Not only are large numbers of people bathing in these waters but downstream the water is used for livestock. Although copper sulphate has been the standard material for the control of algae, and sodium arsenite for rooted weeds, investigations are being conducted to find new and better herbicides as well as to determine the effect of such control on fish populations.

The Role of Fish Predators in Fish Management

The importance of fish predators in the control of excessive inter- and intraspecific competition among fishes has, until recently, been overlooked by fishery biologists and sportsmen. Yet all practical fish management is based on some type of population control with the object of producing for the angling public the maximum numbers of desirable fish. As can be attested by those who have had the opportunity of fishing relatively unexploited waters Nature's system of fish management in which the predators of fish are free to carry on their depredations without interference by man results in precisely the kind of fishing that is the goal of fish management. The fact that fish have lived and thrived under heavy natural predation for thousands of years proves their reproductive potential to be geared to heavy losses. Interest in the conservation of fish predators, particularly fish-eating birds, is increasing and measures are being taken for their protection. Most of the lake states are interested in this problem and are conducting studies to determine the role of predators in maintaining the balance in the fish populations.

Lake and Stream Surveys

Although lake and stream surveys have been conducted for a number of years the present trend in the operation of these surveys is to study the fish populations more closely rather than to make long and detailed investigations of temperature, plankton, abundance of bottom organisms, and other environmental factors. The carrying capacity of streams is receiving a great deal of attention. Methods are being developed and tested to provide more precise measurements of fish populations in both lakes and streams.

REPORT OF DIVISION OF ANGLING

C. N. Feast

During the summer of 1947 I sent to the states a questionnaire regarding fish management. Returns indicated that angling pressure, especially in the interior, has increased in most states to the point where it is very difficult to maintain a reasonable quality of fishing. With few exceptions, at least so far as trout are concerned, fishing pressure in man-hours per season is heavy. Practically all states reported that they had been obliged to resort to the culture of legal-sized trout for distribution in accessible waters, which mostly were either fished heavily or overfished. Most states

suggested that such a program was expensive, and required tremendous organization and quite an outlay in capital investment. On the other hand it seemed to be essential, especially as regards trout, because the natural production of trout apparently does not meet the tremendous demand, with the long seasons and large bag limits that are demanded by most of the people.

Fishing has become a business in our nation. We have a 50- or 60-million-dollar hunting and fishing business in Colorado, a great percentage of which is supported by people wanting to go trout fishing. When such large investment is made in the utilization of a resource it becomes the duty of the game and fish departments to see that the resource is maintained. Chambers of commerce, ranchers' associations, business houses in general, gasoline companies, sporting goods companies, ... all demand reasonably good sport, especially during that part of the year when the weather is conducive to the tourist business.

Administrators are faced with a big task, entailing a tremendous research program, to determine what is necessary to meet that demand. Most states have initiated studies of angling pressure, the catch resulting from that pressure, and of management necessary to maintain acceptable fishing under that pressure. Most states hope to put the study of fish production on a basis comparable to the study of game production. Practically every state has comprehensive figures on the amount of game killed, and on local and regional game problems. Some states have progressed much further in their fishery investigations than have others, but most states have plans to develop methods to determine, if possible, just how many fish of each species are in our waters.

Of course, we in the West are not as well acquainted with warm-water fisheries as are eastern members of the Society. Production of warm-water fish in the east is a matter of utilizing the crop in proportion to the actual production of nature. It cannot be done on an artificial-propagation basis as with trout; consequently the studies involved are chiefly biological and natural-history investigations. There have been more intensive studies and actual data presented for warm-water problems than for trout culture.

Fishing has grown to be of nation-wide importance. It has accordingly become the duty of fishery biologists and economists to study these problems of sustained good fishing. It is my opinion that 5 years from now, in the light of studies made by the various states and by the Fish and Wildlife Service, data necessary in dealing with fish and fish-production problems will be available in such measure as to enable conservation administrators to provide angling, one of the nation's biggest businesses, on a sound basis.

REPORT OF DIVISION OF PROTECTION AND LEGISLATION

Fred A. Westerman

All states and the Canadian provinces have been invited to report upon any important or significant changes in legislation or regulation, and on other developments affecting the regulation of the fisheries under their respective jurisdictions that have taken place since our last annual meeting which it was felt should be recorded in the Transactions.

Replies were received from 38 states, 3 Canadian provinces, and the federal agencies for the United States and Canada. Ten states failed to reply, so we must assume no important changes occurred in Connecticut, Delaware, Idaho, Massachusetts, Nebraska, Nevada, New Jersey, Rhode Island, South Carolina, and Utah.

Twelve indicated that no changes, or at least no important changes, had occurred (Arizona, Arkansas, Georgia, Illinois, Kansas, Kentucky, North Dakota, Oklahoma, South Dakota, Vermont, Virginia, and Washington). Oklahoma reports it has no closed season on any type of sport fishing. The program is said to be very popular and there has been no indication that any game species of fish has become depleted.

License Fees

Thirteen states made changes in the license fees. All involved an increase in revenue, except in **Maryland** where a reduction from $5.50 to $1.75 was made in the cost of a special license permitting residents of the District of Columbia to fish in the Potomac River.

California reports an increase in license fees, commencing in 1948, for sport fishing to cover all species of fish, including mollusks and crustaceans, with reciprocal non-resident licenses but a minimum fee. **Colorado** established a resident alien fishing license for $3.00 and also provided for a license for convalescent military men in the service with no fee indicated. The non-resident fee has been raised from $5 to $10 and a non-resident 3-day license for $3 established. Resident licenses are increased from $2 to $3 effective in 1948.

Iowa increased resident licenses from $1.00 to $1.50. **Louisiana** has increased the non-resident fee from $5 to $10 per year. In **Maine** license fees were established for salmon fishing in tidal waters. These fees apply to both commercial fishermen and anglers with the proceeds earmarked for the improvement of this fishery.

Michigan increased its resident license from $1.00 to $1.50; annual non-resident from $2 to $3; 10-day non-resident from $1 to $2; and added a trout stamp at $1 which both residents and non-residents must obtain to fish for brook, brown, or rainbow trout. **Minnesota** reduced the age limit below which a license is not required from 18 years to 16 years. **Mississippi** increased the license for non-residents from $3.25 to $5.25.

Montana ordered an increase in the non-resident fee from $5 to $10, and made the short-term license at $2.50 valid for only 3 days instead of

10. Only one limit of fish per season may be shipped or moved from the state by non-residents instead of two limits a week. **New Mexico** increased its non-resident license from $3.00 to $5.00.

Pennsylvania increased the resident license from $1.50 to $2.00 and the tourist license from $1.50 to $2.00 good for 5 days rather than 3. Provision was also made for disabled resident veterans of any war whose disability consists of the loss of one or more limbs or of total blindness to be granted a free fishing license. **Wisconsin** now requires a resident angling license from all persons between the ages of 18 and 65 who have resided in the state one year to fish in the inland waters (no license required for angling in the Great Lakes).

Land Acquisition and Acquisition of Fishing Waters

California reports that the "Wildlife Conservation Act of 1947" permits acquisition of lands and/or waters for conservation, propagation, and recreational purposes and provides $3,000,000 annually for the next 3 years for acquisition and construction of facilities for game farms, fish hatcheries, public shooting grounds, . . .

Pennsylvania has earmarked 25 cents from each resident fishing license for: the acquisition of fishing waters; or of lands which can be converted into ponds, dams, or reservoirs for fishing; the rebuilding of old dams; and the study of problems relating to better fishing.

Discretionary Power

Several states made reference to the authority which has been delegated to their respective conservation commissions in making regulations for the administration of the fisheries. Discretionary power was one of the important principles in the North American Fish Policy prepared and adopted by the Society.

Arkansas now has regulatory powers, but changes in regulations have been deferred until facts rather than public desires can be made the basis of change.. The **California** legislature has granted certain regulatory powers for the commission, affecting both fish and game. In **Colorado** the bills enacted in 1947 give the game and fish commission "authority and regulation of game and fish." Under House Bill 667 seasons may be opened or closed on a 2-day notice.

Florida is involved in a court action to test the validity of the discretionary power vested in its game and fresh-water fish commission. On October 1, 1946, an order of the commission prohibited the sale of fresh-water fish other than catfish, gar, and mudfish taken from the waters of Lake Okeechobee and the St. Johns River. Before this date only the sale of black bass was prohibited. The 1947 legislature voided this regulation by passing a law which exempts violators of this order from any penalties. On the basis of two court decisions declaring this Act unconstitutional, the order is again being enforced, but it is expected the case eventually will reach the Supreme Court.

Discretionary power in **Iowa** was expanded to include setting size limits on fish.

In **Missouri** and amendment to the state constitution was adopted November 3, 1936, whereby all regulatory powers relating to fish and other wildlife resources have been vested in the conservation commission since July 1, 1937, when it became effective. We are informed that this amendment and its provisions were incorporated in the revised constitution, adopted February 27, 1945. No other state has gone so far in delegating authority for the management of its fish and wildlife.

Tennessee reports that the conservation commission was granted the power by the 1947 General Assembly to set fishing seasons, creel limits, and size limits.

Regulations Affecting Sport Fishing

California has reduced the daily creel limit on trout from 25 to 15.

Colorado enacted a law on the importation, exportation, and transportation of game and fur beaver, which was established to prohibit commercializing either game, fish, or birds. All waters east of Highway 81 have been opened to both day and night fishing during the open season.

Indiana has provided for issuing permits to possess or own a spear or gig for use in taking noxious fish.

Louisiana has repealed an act of 1944 which provided a closed season of 2 months on three species of game fish. The daily creel limit on striped or yellow bass and on white bass has been increased from 15 to 25 and the size reduced from 10 inches to 7 inches.

The legislature in **Michigan** lengthened the season for taking brook, brown, and rainbow trout by making the last day of the open season the second Sunday in September rather than Labor Day. Provision was made also to permit the taking of minnows for commercial purposes from trout streams or portions thereof to be designated by the Director of Conservation under such regulations as he may prescribe. Another change authorized the Director of Conservation to permit fishing in any manner at any time conditions indicate that winterkill is imminent.

The Commissioner of Conservation in **Minnesota** has been authorized to establish a list of not more than 50 lakes at any time which have been found to contain an unbalanceed fish population in which the Commission may prescribe the seasons, limits, and methods of taking fish. This authority is a step toward better fish-management practices.

Missouri reports the removal of size limits on the species of game fishes that tend to stunt, longer open seasons for game fishes, and lower creel and possession limits on all fishes. Added restrictions have been imposed for taking non-game fishes by gig or spear and on the taking of minnows from public waters for commercial purposes.

The **Ohio** Conservation and Natural Resources Commission promulgated an order which for experimental purposes removes closed seasons, legal lengths, and bag limits from several of the more important lakes.

Texas advises that further restrictions were placed upon the taking of minnows from streams.

In **West Virginia** the common names of game fish were changed to "the common names now widely used in the United States." Minimum size limits were eliminated on the rock bass, black and white crappies, and bluegill.

The **Wyoming** commission under its wide discretionary power has recently placed a ban on the use of live fish as bait and prohibits fishermen from having them on or near streams and lakes. The game and fish law also bars the use of salmon eggs and kernel corn as fish bait.

Congress amended the federal black bass law which makes it an offense to bring into interstate transportation black bass caught in violation of state laws, to extend coverage to all game species. One exception was made for the steelhead trout which are open to legal commercialization in some states.

The Federal Aid to Fisheries bill comparable to Pittman-Robertson Act made some progress but was not acted upon and will be up again for consideration when Congress reconvenes.

From the **TVA** comes word that the discarding of closed seasons by the state conservation departments in those waters 3 years, and on some waters 4 years ago, has resulted in the best fishing in 1947 that has been experienced.

The Province of **Ontario** has made a number of revisions in the open and closed seasons on black bass, muskellunge, brook trout, rainbow trout, brown trout, and yellow pikeperch.

Manitoba plans to lower the present daily creel limits and possession limits for the year 1948.

Regulations Affecting Marine and Commercial Fisheries

Congress has authorized a broad-scale program of fishery investigation in the central and west Pacific waters, intended to foster the development of an expanded commercial fishery.

Another Act authorizes the States of **California, Washington** and **Oregon** to enter into a compact for the conservation and protection of the marine fisheries in which those states are interested. California reports approving the compact with Oregon and Washington, so definite progress is being made. That state also has made a number of material changes of a restrictive nature in its commercial fishing regulations in the interest of better management.

In **Alabama** waters, menhaden fishing has been stopped.

New York enacted legislation substituting a minimum mesh size of not less than 4 inches in flounder nets used in the waters of Long Island Sound for a minimum size limit on the fish. Another law requires a bottom slat measurement of $1\frac{5}{8}$ inches on all lobster pots to prevent illegal traffic in undersized lobsters.

British Columbia has made several amendments to its fishery code.

The most important is the granting of authority for the fishery department to regulate the harvesting of the various types of seaweeds.

The Dominion Department of Fisheries calls attention to 17 amendments to the federal fishery regulations that have been made during the current year.

Miscellaneous

In **North Carolina**, where the administration of fish and game matters has been more or less a political football for many years, the General Assembly this year placed fish and game affairs under a new department known as the North Carolina Wildlife Resources Commission. However, commercial fisheries were left in the Department of Conservation and Development.

Oregon presents a somewhat confusing situation. An Act was recently passed placing the control of angling for salmon under the Oregon Fish Commission which also is responsible for commercial varieties of fish and shellfish. A separate Game Commission, however, is responsible for game fish, birds, and game. The Act requires that the Game Commission concur in the regulations set up by the Fish Commission; otherwise they do not become effective. The enforcement of fish and game regulations is under the jurisdiction of the state police which situation further complicates matters.

Wisconsin enacted legislation which enables the Conservation Commission, the State Board of Health, and the State Department of Agriculture to regulate the use of insecticides in forest and non-crop areas. It is aimed at controlling the use of DDT to prevent damage.

REPORTS OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS

H. J. Deason

In the present day, when much that goes on in the world has an international flavor, it is difficult to compile and present an adequate and comprehensive report on international matters as they affect the fisheries. An adequate report, if any man or group of men were to attempt its preparation, would require a full volume rather than a few pages in the Transactions.

Since choice had to be exercised in compiling material, it was considered that the Society by reason of its interest in the conservation of natural resources and in the techniques of management would be most interested in a review on international matters in those fields. Thus, the present report deals with matters of conservation and management of natural resources, and with the tools of conservation. Economic considerations as they affect the fisheries have been omitted, not because they are without importance, but because they are of secondary interest to the majority of the members of the Society.

International Fisheries Commission (Halibut).—The International Fisheries Commission, established by convention between Canada and the United States and responsible for the regulation of the Pacific halibut fishery, has continued to make progress in the rehabilitation of the fishery.

Regulation has further improved the condition of the stocks of halibut and increased the abundance of the species, as indicated by the marketable catch per standard unit of fishing effort, on all the fishing grounds. In the long-fished area off the coasts of Washington, British Columbia, and southeastern Alaska where the stocks were reduced most seriously by overfishing before regulation, the abundance of halibut in 1946 was 145 percent above the all-time low level of 1930. In the more recently explored and less seriously overfished area extending from Cape Spencer, Alaska, to the Aleutian Islands, the abundance was 95 percent above the 1930 level.

As abundance has increased the Commission has gradually increased the amount of the annual catch that may be taken. In 1946 the catch for the entire coast was slightly above 60,000,000 pounds (with heads off and entrails removed) or almost 17,000,000 pounds greater than the catch that the unrestricted fishery was able to take in 1931, the year before regulation began. This rise in production in 1946 alone was worth more than $3,000,000 to the fishermen of the United States and Canada and was more than two and one-half times the total expenditures of the Commission during the 23 years of its existence.

The greater abundance of halibut has correspondingly reduced the effort and time required to take the annual catch. The 1946 catch, though al-

most 40 percent greater than that of 1931, was taken with about one-third less fishing effort.

The halibut regulations consist mainly of a division of the coast into areas, the setting of annual catch limits for the areas and the closure of the areas as their catch limits are attained. The catch limits are supplemented by a statutory closed season at the time of spawning, the permanent closure of two nursery areas, and the prohibition of destructive types of fishing gear.

The regulations are based upon extensive biological, statistical, and oceanographical investigations and are guided currently by a system of statistical and biological observations of the changes in the condition of the stocks as a result of regulations. Most important of the current observations are those showing the changes in the relative abundance of fish and in the size and age composition of the stocks. Tagging experiments to define populations and special investigations are undertaken as the need for them arises.

The work of the Commission demonstrates the feasibility of international control of an international fishery and what can be achieved by the rational application of such control to a depleted fishery.

International Pacific Salmon Fisheries Commission.—Under the terms of the Convention ratified by Canada and the United States on July 28, 1937, the International Pacific Salmon Fisheries Commission studied the life history of the sockeye salmon and related problems for 8 years before undertaking the regulation of the fishery. During this time it was found that railroad construction had altered conditions at Hell's Gate, 133 miles from the mouth of the Fraser River, so as to form an almost complete obstruction to salmon migration at certain water levels. Fishways have been completed which allow the sockeye to pass around the area without delay. The Commission must now rebuild the early "upriver" runs through careful regulation of the fishery and by aids to natural propagation.

The principal structures at Hell's Gate were completed on May 8, 1946, and were in operation for the sockeye runs between July 11 and the end of September. Construction on a "high-level" fishway to overcome blockade conditions at levels above 50 feet is to be completed in time to safeguard early runs passing at high-water levels in the spring of 1947.

The fishways at Bridge River Rapids were completed on April 30, 1946, and operated successfully during the former block levels. Engineers have designed a series of five fishways for Farwell Canyon and the easements and rights-of-way have been obtained by the Dominion Government. On Kynoch, Forfar, and Rossette Creeks, log jams were removed in an effort to stabilize and define the stream beds and to allow sockeye to utilize a greater spawning area. Surveys of the obstructions on Weaver Creek, in the North Thompson and Queenel watersheds, and for Black Canyon, have been completed.

In 1946, Canada and the United States regulated for the first time the sockeye salmon fishery in the waters defined by the Treaty. In summary

the 1946 regulations were as follows: (a) the United States fishery and Canadian fishery to the south of Vancouver Island opened on July 25; (b) the Canadian fishery in the Fraser River and the Gulf of Georgia opened on August 8; (c) week-end closures of 36 and 48 hours were allowed in the United States and Canadian waters respectively; (d) from June 1 to the opening of the sockeye fishery only a gill-net fishery with nets of 8-inch or greater stretched mesh was permitted.

The number of fish found on the spawning grounds was of especial significance in 1946 for it shows the effect of the protective regulations as well as free passage through Hell's Gate. The increase in the "upriver" runs is illustrated below:

Tributaries	*1942*	*1946*
Bowron River	1,826	6,951
Chilko River and Lake	34,109	59,000
Stellako River	48,640	245,799
Qesnel Lake	0	61
Raft River	450	3,000
Seymour River	1,950	2,619
Stuart Lake tributaries	8,198	9,609

A large run of sockeye spawned in Francois Lake (above the Stellako River)—the first time a large body of fish has ever been reported from that area. No estimate of the number of lake spawners could be made.

Obstructions to sockeye migration were detected by a series of extensive tagging programs beginning in 1938. Such experiments have been continued in 1946 with 6,730 tags released at Hell's Gate, 2,459 at Bridge River Rapids and 1,967 at Farwell Canyon. The results show that the fishways at Hell's Gate and Bridge River Rapids functioned efficiently over the levels for which they were designed and neither delay nor mortality was found. At Farwell Canyon conclusive proof of mortality was not only found at the main falls but throughout the upper reaches of the rapids.

Canadian members of the Commission are A. L. Hager, Chairman, A. J. Whitmore and Tom Reid, M.P., while the United States members are Fred J. Foster, Secretary, Edward W. Allen, and Milo Moore.

Food and Agriculture Organizations of the United Nations.—The FAO was established in Quebec in October 1945 to contribute to an expanding world economy by raising levels of nutrition and standards of living, improving the production and distribution of food and agricultural products, and bettering the conditions of rural populations.

Dr. D. B. Finn, formerly Deputy Minister of the Canadian Department of Fisheries, was appointed Director of FAO's Fisheries Division in July 1946. Since that time the Fisheries Division has been organized and partially staffed with international fishery experts, the Second Session of the Conference has been held in Copenhagen, and the Third Session of the Conference began its meetings in Geneva on August 25.

At Copenhagen the technical Fisheries Committee of Commission A

was composed of representatives from 16 of the 47 member nations. As a Committee it reported on a number of items including the place of fisheries in a World Food Board, the recommendations of the Special Meeting on Urgent Food Problems, the future fisheries work of the Emergency Economic Council for Europe, the UNRRA program, the relationship of FAO to International Government and Public Bodies, the organization of FAO's Fisheries Division, and the need for more adequate international statistics.

The Director-General's proposals for a World Food Board were considered by an FAO Preparatory Commission which met in Washington from October to January. As a result of its meetings, FAO's Fisheries Division was requested to submit an interim report on salt fish by July 15, 1947, and a further report by the end of the year 1947. An *ad hoc* committee of experts from 10 countries, called together by the Fisheries Division in April, met in Washington. The July report has been issued and work is underway on the December report.

Meanwhile a meeting has been held in Rome to discuss means of widening the distribution of fish in Europe. For the next year a representative of the Fisheries Division has been detailed to the FAO Regional Office in Rome.

The fishery matters on the Agenda for the Geneva Conference include discussion of the following subjects: the establishment of Regional Councils For Study of the Sea; the development of minimum international standards of quality for fishery products; the world census of food and agriculture for 1950; a progress report on the salt-fish commodity study; and recommendations of the Rome meeting.

The program for FAO's Fisheries Division during 1948 as recently announced entails the expenditure of $196,365 and the employment of 33 persons. The Division is organized into three branches: Economics and Statistics, Technology, and Biology. Heads for the latter two sections are still being sought and, among other top positions, that of Assistant Director of the Division is vacant.

The 1948 program of FAO contemplates, in addition to the items on the Geneva agenda: (1) assistance in the establishment of a Southeast Asia Institute to develop fishery methods and technology; (2) development of common conversion factors and uniform methods of reporting; (3) collection of statistics on landings, processing, and trade; and (4) issuance of a Yearbook on Fisheries Statistics, a technical quarterly Journal of Fisheries, a Monthly Bulletin of Fisheries, and rosters of technical workers and organizations in the fishery field.

Other planned work includes a catalogue of fishery resources; recommended nomenclature for commercial fishes; establishment of a clearing house for periodic reports on research in handling fishery products; survey of methods of fishing; and the supplying of technical advice to Member Governments on statistical services.

Rehabilitation of Philippine Fisheries.—The war had a number of far-

reaching effects upon the fishing industry of the Philippines. Much equipment was lost, destroyed, or removed in the course of military operations. Additional equipment was lost because of the inability of the industry to obtain materials for repairs and replacements. The most highly developed and efficient segment of the industry—the offshore vessel fishery for pelagic species—was operated by alien Japanese interests before and during the war. The removal of the Japanese and the loss of their equipment and facilities had a profound effect on fishery production from the general area.

Prior to the war, the Philippine fishery, ranking about fifteenth among the nations of the world, was quite inefficient. Measured in terms of production per man per annum, the average of the Philippine fishing industry was less than 1,500 pounds. This average productive capacity may be compared with 7,000 pounds per man per annum in Australia and Japan; 10,000 in Canada, France, and Sweden; 32,000 in the United States; and 63,000 in Great Britain—all pre-war averages.

For the purpose of giving technical aid in the rehabilitation, development, and modernization of the fisheries of the Philippines, Congress authorized the Fish and Wildlife Service of the Department of the Interior to undertake such a program in cooperation with the Government of the Republic of the Philippines. (Sec. 309, Public Law 370, 79th Congress, approved April 30, 1946). A working agreement was signed by representatives of the United States Government and the Philippine Government on March 14, 1947, and the first appropriations for the work became available in August 1946.

The program, begun on a preliminary basis in March 1947, was in full-scale operation by August of the same year. It has several parts as outlined in the following paragraphs.

(1) Offshore experimental and exploratory fishery operations, coupled with the necessary biological and oceanographic investigations, are being conducted to determine the abundance and availability of fish in offshore waters and to determine the most effective methods of capturing the fish. Two modern vessels have been obtained and outfitted for this purpose. The *Spencer F. Baird* is a combination tuna clipper and oceanographic vessel with all modern facilities and equipment for research and experimental work. The *Theodore N. Gill,* a combination purse-seiner and otter-trawler, is equipped to handle full-scale purse seines, trawls, long lines, shark gear, and other fishing equipment. By means of cold-storage and sharp-freeze facilities in the after hold the vessel is used for experiments in the handling, processing, freezing, and storage of fish at sea.

(2) To aid in modernizing the inshore fisheries, small boats with motors and other improvements over existing craft are being outfitted for experiments and demonstrations. The objective is to make methods more efficient in the interest of improving the utilization of manpower, and thus contribute to greater financial returns for individual fishermen.

(3) The pondfish industry is being assisted by surveying sites and aiding in the establishment of new ponds of improved design, and in testing

and adapting techniques of fertilization, aeration, disease control, noxious weed control, and artificial feeding in an effort to curtail losses and improve the yield.

(4) Through a technological laboratory ashore, assistance is being given in the development of improved methods of dressing, handling, transporting, salting, freezing, smoking, and otherwise preserving the catch in order to improve quality, avoid waste, and develop new edible products. Research is being conducted also to develop methods of processing by-products from waste portions of the catch and from inedible fishery products.

(5) In collaboration with representatives of the Philippine Bureau of Fisheries, efforts are being made to improve the transportation, marketing, and distribution of fishery products to make more food available at lower prices in the principal consuming centers.

Training for Foreign Students.—Under the program of the United States Government for Cultural and Scientific Cooperation with the American Republics, as in former years, the Director of the Fish and Wildlife Service awarded a number of training grants to qualified students from the American Republics during the past year. Students from Argentina, Peru, Bolivia, Brazil, and Uruguay are now in the United States studying fishery specialties in field establishments of the Fish and Wildlife Service and are pursuing part-time courses in universities and colleges. Under the Philippine fishery rehabilitation program, the Fish and Wildlife Service is obligated to train, prior to June 30, 1950, not to exceed 125 Filipinos in "methods of deep-sea fishing and other techniques related to development of the fisheries." Twenty-one students began training in May 1947, and after an orientation course at the Maritime Commission School at Alameda, California, the majority were apprenticed to the fishing industry where they are receiving practical training in fish production and processing. A few are being provided training in fishery biology and fish culture. Forty additional students will be trained during the coming year.

The interest in training in fisheries, especially in fishery technology, on the part of foreign students is increasing. The Government of India subsidized a large number of students last year who came to the United States for training. Students from other countries in varying numbers are seeking fellowships, scholarships, and grants-in-aid so that they may come to the United States for training. Existing legislation does not authorize the Federal Government to assist foreign students, except from the American Republics and the Philippines, although such legislation was passed by the House of Representatives and was reported favorably to the Senate during the first session of the 80th Congress. Schools in the United States are not prepared to give training in fishery technology, as such, and it is hoped that universities and colleges—in addition to the University of Washington which is taking such action—will become cognizant of the need for providing training in the economic and industrial aspects of the fisheries, and will become aware that training in fishery biology and cog-

nate subjects is no longer adequate to fulfill the needs and requirements of students either from the United States or from abroad.

Revival of Fishery Research Abroad.—European countries appear largely to have resumed their fishery research activities and the publication of technical papers which were suspended during the war years. Even in Eastern Europe, especially in Poland and Czechoslovakia, fishery research on the part of individual investigators is being resumed and requests for publications and assistance in procuring research materials are being received in the United States in increasing volume.

Assertion of Jurisdiction over the Fisheries of the High Seas.—The issuance by the President of the United States, on September 28, 1945, of a proclamation asserting the intention of the United States to establish conservation zones in certain areas of the high seas adjacent to its coast, for the purpose of protecting fishery resources in which the United States has a sole interest was reported in detail to the Society at the 1946 meeting. The same proclamation also indicated that where certain fisheries of the high seas were prosecuted jointly by the United States and other nations, the United States would seek to enter into international agreements with the other countries concerned for the purpose of providing for international cooperation in the management of the fishery resources.

Also reported to the Society last year was the issuance of the Mexican proclamation on October 29, 1945, in which the Mexican Government went considerably farther than the United States by asserting her *ownership* of the fishery resources adjacent to her coasts out to the 200-meter contour. The Mexican proclamation has not yet entered into force since it has not received ratification by the legislative bodies of two-thirds of the Mexican States.

The Argentine Republic (October 11, 1946), Chile (June 25, 1947), and Peru (July 1947), all have issued similar proclamations which they assert follow the same pattern as that of the United States, but actually follow the general pattern of the Mexican proclamation of asserting sovereignty and ownership. The Chilean proclamation is most extreme—asserting jurisdiction out to a distance of 200 nautical miles from the nearest point of land, and although the avowed purpose is to conserve the resources it is feared that regulation for purposes of revenue may be the major objective. The Chilean and Peruvian documents make no provision whatever for fishing rights of other nations in the waters affected, and joint regulation by international agreement is not considered. The United States Government has before it a very difficult and delicate task of insuring that the future implementation of these proclamations of other countries does not jeopardize legitimate interests of the United States in the fisheries of the high seas.

Great Lakes Fishery Treaty.—The Great Lakes fishery treaty, concluded by the United States and Canada on April 2, 1946, has not yet entered into force since it has not been ratified. The crowded calendar of the Committee on Foreign Relations of the United States Senate prevented its

consideration during the first session of the 80th Congress. It would be well for the Society at this meeting to reaffirm its resolution of last year recommending early ratification and the passage of appropriate implementing legislation.

New International Convention for the Regulation of Whaling.—An international Whaling Conference was held in Washington November 20 to December 2, 1946. Plenipotentiary or observer delegations were in attendance as follows: United States of America, Argentina, Australia, Brazil, Canada, Chile, Denmark, France, Iceland, Ireland, the Netherlands, New Zealand, Norway, Peru, Portugal, Sweden, the Union of South Africa, the Union of the Soviet Socialist Republics, and the United Kingdom of Great Britain and Northern Ireland. Mexico was invited but did not participate.

Two new international agreements resulted from the Conference: (1) A Protocol for the Regulation of Whaling, effective only for the 1947–48 whaling season; and (2) an International Convention for the Regulation of Whaling, which replaces former basic international whaling agreements, as amended, and becomes effective for the 1948–49 and subsequent whaling seasons. The International Convention for the Regulation of Whaling represents primarily the recodification and amendment of whaling regulations contained in previous agreements, with the outstanding new feature that an International Whaling Commission is established which is empowered to make changes from time to time in the whaling regulations. Formerly, even the most minor changes in regulations could be effected only through the medium of a full-dress international conference, the signing of an instrument, and ratification of the signatory nations.

The Protocol and the new International Convention were considered by the United States Senate, which body gave its advice and consent as to ratification on July 2, 1947. The United Kingdom of Great Britain and Northern Ireland also has ratified. Ratification of the Convention by the Netherlands, Norway, the Union of Soviet Socialist Republics, and one other signatory nation are necessary before the Convention can enter into force. It is hoped that such ratifications will take place and that the first meeting of the new International Whaling Commission may take place during 1948.

Proposed Northwestern Atlantic Fishery Treaty. Popular interest has grown considerably in a treaty that will provide for international regulation and management of the fishery resources of the Northwestern Atlantic Ocean. Signs of diminution in the New England fisheries and the increasing magnitude of operations on the Grand Banks by vessels of European nations have caused the popular interest in such a convention in the United States and Canada. Many informal conversations of government officials with regard to such a treaty have been held during recent years, and work toward a treaty is being intensified by reason of a special 1-year appropriation of $25,000 made by the United States Congress immediately prior to the July adjournment. Major interest in such a treaty is vested in

the United States, Canada, Newfoundland, and France, since they have territorial interests in the Northwestern Atlantic. Certain European nations have to be considered, however, since they have historical fishing rights in the area. These latter include Portugal, Spain, Italy, and others. It must be remembered that the interest of Europe in the fisheries of the Northwestern Atlantic grew out of over-exploitation of waters close at home. Standards of conservation of marine fishery resources are lower in Europe than in North America. If eventual depletion of the Northwestern Atlantic fisheries is to be avoided, some means of regulation will be necessary in the not-too-distant future. This Society should look with favor upon the proposed treaty negotiations.

Cooperation with American Republics.—Throughout the past year the program of technical cooperation with the American Republics, authorized by Congressional enactments in 1939 (Act of May 3, 1939, 5 U.S.C. 118e; and Act of August 9, 1939, 22 U.S.C. 501) was continued. A comprehensive report on the inshore and offshore fisheries of Chile with recommendations for the expansion of the fishing industry and the conservation of the resources was completed. This survey resulted from the assignment during 1945 and early 1946 of four experts from the Fish and Wildlife Service, whose expenses were defrayed by the Chilean Government. During May 1947, a biological survey of the fishery and wildlife resources of Guatemala, which began the previous year, also was completed by biologists loaned by the Fish and Wildlife Service. The fishery mission to Mexico, which has operated continuously since 1942, is operating under a new 2-year inter-governmental agreement concluded in Ocotber 1946. It provides for the assignment of two specialists from the Fish and Wildlife Service who are conducting biological investigations of the fishery resources as well as advising the American Embassy on international negotiations involving the fisheries. During the present month a survey of the shrimp and sardine resources of Venezuela is being undertaken by a biologist of the Fish and Wildlife Service, assisted by Venezuelan nationals. The Venezuelan Government is defraying the entire cost, including the purchase and outfitting of an experimental fishery vessel of the shrimp-trawler type. A request has been received from the Panamanian Government for the loan of a mollusc expert to investigate a disease that is affecting the mother-of-pearl shells that constitute a valuable Panamanian export product. Expressions of interest in the assignment of experts from the United States have been received from other Central and South American countries.

Although certain segments of the domestic industry view the assignment abroad of such experts with considerable concern because it is anticipated that the expansion and development of fishery industries will lead to competition with products from the United States on foreign export markets, this concern is largely without justification. Countries needing technical assistance will acquire it somewhere. It is vital to the foreign policy of the United States to supply technical aid to foreign governments, upon request, rather than refuse to do so and permit technical experts from

other foreign countries whose policies and motives are inimical to the security of the United States to undertake the assignments. This Society is well aware that Germany and Japan specialized in this field—as a blind for espionage—prior to 1939, much to the detriment of the interests and security of the Allied Powers. The United States has much to gain economically from any action that stimulates industrial growth and advancement in the Western Hemisphere, as supplies and equipment are most readily available in the United States. Since German and Japanese fishing gear and internal-combustion engines have not been available, Central and South American Countries have been importing from the United States. They like our goods and the service on repair parts and replacements is prompt.

Conservation in Relation to the Proposed Japanese Peace Treaty.—A few weeks ago the United States Government announced its intention to call an international conference of the principal Allied Powers for the purpose of drafting a Japanese Peace Treaty. Now is the time for all persons and organizations interested in conservation to remember Japan's former attitude toward conservation. (1) She was a party, with the United States, Canada, and Russia, to a four-power treaty which provided for the conservation and management of the fur-seal herds of the North Pacific, which treaty she abrogated in 1941 on the flimsiest of pretexts and excuses—contending that the fur-seals were eating food fish although all food studies made prior to that time showed that fur-seals ate only small proportions of species of fish that are caught for the market. (2) Japan was a party to the 1931 Geneva Convention for the conservation of whales, but it did not suit her convenience to ratify. From that date until she ceased whaling operations during the war she wantonly ignored seasons, size limits, and other regulations established by international agreement. (3) Japan had fishery enterprises flung throughout the Pacific and we know now what we only suspected before—that Japan was expanding her fishing areas toward North America and to the southward because, primarily, she had depleted the resources adjacent to her coasts.

For the foregoing compelling reasons it is believed that the Japanese Peace Treaty must contain assurances that Japan henceforth will become a party to any international agreements for the conservation of natural resources that are concluded or operative with respect to any resource she exploits, that Japan will abide by any international conservation regulations, and that Japan will establish a sound system of conserving her own resources so that they will not be depleted.

The Allied Military Government is doing a good job of educating the Japanese people in the principles of conservation. Education of the masses is not a sure method where exploitation of natural resources constitutes big business. Japan cannot again be trusted; she must be forced to conserve. It is believed that a resolution of this Society addressed to the Secretary of State is in order.

COMMITTEE ON COMMON AND SCIENTIFIC NAMES OF FISHES

WALTER H. CHUTE

Editor's Note: The report presented by Mr. Chute comprised a list of common and scientific names for 570 species of fish. After some discussion by the Society the report was adopted and the Editorial Board instructed to proceed with publication of the list at the earliest possible date. Pursuant to these instructions, the Board in 1948 issued the report as Special Publication No. 1, *A List of Common and Scientific Names of the Better Known Fishes of the United States and Canada.* The list was subsequently reprinted as an appendix to Volume 75 of the TRANSACTIONS.

EDITORIAL BOARD

RALPH HILE

Should the driver of a car become hopelessly stalled in the mud of a back-country road, there are several perfectly useless things that he might do. He might heap curses on the manufacturer of the unfortunate vehicle, he might impugn the integrity of all highway officials from the township to the Federal level, or he might attempt a more complete coverage by railing at the general perversity of fate. All this would accomplish little for our unhappy motorist other than to place additional and potentially lethal strain on his coronary artery. In his situation action, not recrimination, is indicated.

In the publication of the TRANSACTIONS of the American Fisheries Society we have got ourselves stuck in the mud. The circumstances that did contribute or may have contributed most to our embarrassment are easily listed: absence of members of the Editorial Board on military duty; excessive war-time and post-war burden of official work of Board members; negligent and dilatory attitude of Board members; over-crowded schedules and shortages of material in the print shop; negligence and unwarranted delay on the part of the printer; difficulties in obtaining materials for publication during a period in which no meetings were held and research activities were reduced; careless preparation of manuscripts that reduced editorial efficiency and thus lengthened the time required for editing; . . . A listing of the causes of our current predicament is useful; we need to recognize that which we must correct. On the other hand, to attempt to go further and assign to each of these several causes its proper fraction of the total blame would serve us not at all in our immediate problem of extricating ourselves from the mud. Our energies are better directed toward an appraisal of our present status and a planning for the future. In the remainder of this report, therefore, I shall limit myself to a description of the activities of your present Editorial Board and a forthright statement of what I believe to be our future prospects.

When the present Board assumed responsibility for the publication of the TRANSACTIONS, it inherited Volume 76 and along with it the material

(business transactions, symposium, papers) from last year's meeting. At the same time we were accorded the unsolicited privilege of guiding the fortunes of Volume 75. That volume came to us destitute of anything but a number. Inasmuch as long-established convention calls for the publication of Volume *n* in advance of Volume *n* + *1*, our immediate concern was papers for Volume 75. By means of a continent-wide canvass for manuscripts and a certain amount of pilfering from Volume 76 we had accumulated sufficient materials for a passable if not impressive volume by early spring of this year.

Then came the problem of printing. Since it was perfectly obvious that Volume 74 was progressing at a snail's pace and that to await its issuance would entail further great delay, we considered two possible methods of expediting the printing of Volume 75. Under the first it was proposed to locate a new printer for Volume 75 while we turned Volume 76 over to our present printer. Thus two volumes would be in press simultaneously. That idea was abandoned when we learned that the Michigan Academy of Sciences, Arts, and Letters, which was attempting a similar strategy, had been turned down by seven different printers. Under the second method it was planned to persuade our present printer to begin work on Volume 75 while Volume 74 was still in press. This idea also came to naught. On April 18 of this year I wrote to Mr. John Ferguson 3rd, Vice-President of Monumental Printing Company, as follows:

> As editor of the TRANSACTIONS of the American Fisheries Society effective with Volume 75, I am writing to inquire as to when you will be in position to accept materials for that volume.
>
> As you are aware, we are sadly in arrears in the publication of the TRANSACTIONS: Although our 77th meeting is scheduled for next September, we are just now in the process of printing the 74th volume. This situation obviously requires correction at the earliest possible moment. I am sure that the members of our Society who have been extremely patient in the past will not much longer retain their tolerant attitude toward these excessive delays in publication.
>
> As a step toward a return to normal schedule, I should like to request your cooperation in issuing Volume 75 with a minimum of delay. On my part I assure you that I will carry out the work of distributing and correcting proofs and of preparing the index as rapidly as I can. I am in position now to send you between 15 and 20 manuscripts and will be able to forward the remaining materials within a few more weeks.
>
> I shall appreciate hearing from you at your early convenience.

Mr. Ferguson's reply of April 21, which is quoted in part below, opened with an important concession and a marvelous understatement of fact:

> Volume 74 of the Transactions has not been well-handled by the editor and us equally. . . .
>
> . . . . We have set the new and, I believe, final material for 74. It is now being paged, and page proofs will be delivered before the end

of the week. If we have a prompt return, with OK, the printing itself will require very little time.

. . . . Once the page proofs are cleared we could start number 75 without any confusion in handling. We are prepared to do the type-setting and page make up promptly, and I will be glad to be able to shake off the notion that the TRANSACTIONS are in no hurry.

The hoped-for early completion of Volume 74 failed to materialize. Proofs were still in circulation in July and the indexing did not begin until August. After I learned that the indexing of Volume 74 was underway, I wrote Mr. Ferguson again on August 20:

Dr. Deason advises me that he is about to complete the indexing of Volume 74 of the TRANSACTIONS of the American Fisheries Society. With the work on that volume so well along I am wondering whether you may not now be in position to accept the materials for Volume 75. I can send you the manuscript for the entire volume except, of course, the index at any time.

As I explained in my letter of April 18, our situation with regard to publication of the TRANSACTIONS is desperate. We are in arrears with Volumes 75 and 76, and materials for Volume 77 will come to me this fall. From a strictly personal standpoint I should like to be able to report some progress on Volume 75 at the time of our meeting in Denver September 11 and 12. If I am able to do so, my chances of returning safely to Ann Arbor should be greatly improved. Please advise.

Mr. Ferguson replied on August 22:

Yes, it does look like Volume 74 is moving at last to its close. I shall certainly be glad.

So send us your material for Volume 75. I can see no reason why, now, there would be any confusion. We will start on it at once, and you can so report at the Denver meeting.

On August 28 all of the materials for Volume 75 had been checked, packed, and shipped to the printer.

As for the future, we offer hope but promise nothing except our very best efforts in getting the TRANSACTIONS again on schedule. With full cooperation from the printer Volume 75 can be issued early in 1948 and Volume 76 in the latter part of that year. It is conceivable even that Volume 77 covering the present session might be ready or nearly ready for press before we convene again. Perhaps we should not hope for so much. It does seem certain nevertheless that we have passed the period of falling further and further behind and are about to begin a recovery, at what rate only time can tell.

REPORTS OF SPECIAL COMMITTEES

COMMITTEE ON POLLUTION STUDY

KENNETH A. REID

Everyone in this audience is conscious of the existence of water pollution and of the dire need of doing something about it. It is idle to contend that existing authority is adequate when present pollution is the result of existing authority or lack of it. The only way the desired objective can be accomplished is by federal enforcement authority, which would eliminate the effective argument of competitive disadvantage to industry that has so long minimized or nullified state efforts because it is so plausible.

It is now nearly 12 years since the first of the present pollution-control bills was introduced in Congress. In the beginning such bills were opposed by a solid front of industry, regardless of whether any particular industry was a polluter, by the municipalities who did not want to go to the expense of putting in sewage-treatment systems, and by states that were apparently controlled by these two groups. During the past few years the industrial opposition has diminished materially and, odd as it may seem to some, the principal opposition—the opposition that kept any bills from passing—came from the state health authorities and sanitary engineers.

Last October I represented the Izaak Walton League at the first of several conferences with representatives of state health departments, sanitary engineering associations, interstate compact agencies, Council of State Governments, and other groups which had formerly opposed any actual federal control. As a result of these conferences at which were resolved the differences between those who wanted federal study, investigation, and spending but no federal control, and those who wanted federal control in addition, all of the present group of bills in the 80th Congress contained provision for some degree of federal control.

Just when all forces, except a few die-hard industrial polluters, had reached agreement on the essential principles of the needed legislation, a new approach was injected by the Federal Works Administration. General Fleming of this agency appeared before both the Senate and House Committees with a completely new version of a bill which, on the philosophy that pollution was not a public health or wildlife matter but an unemployment matter, substituted the Federal Works Agency for the U. S. Public Health Service as administrative agency, eliminated all enforcement provisions, and proposed building up a great backlog of surveys so that the work of municipal sewage-treatment plants could be started where and when unemployment needs dictated. After some negotiation between the Federal Works Agency and the U.S. Public Health Service a composite bill was drafted making the latter organization the administrative agency to

determine where and when the work should be done, and the Federal Works Agency the one actually to undertake the construction work.

After this change, Congressman Karl Mundt wrote a new bill embodying all the agreed principles, the suggestions of the Legislative Counsel, and the joint administration by the U.S. Public Health Service and the Federal Works Agency. This bill, H.R. 3990, was still before the House Public Works Committee when Congress adjourned. But shortly before the adjournment of the first session, the Senate Public Works Committee, after rewriting S. 418 along the general lines of H. R. 3990, reported the amended bill favorably so that it will be before the House for consideration when Congress convenes in January.

In its general form this Committee revision of S. 418 embodies many desirable features. It is, however, extremely weak in certain particulars which would indicate that industrial polluters exerted strong pressure on the Committee after the hearings were over. Here are the defects: (1) deletion of the provision that compliance with the terms of the Act shall not be conditioned upon availability of federal finance; (2) omission of the provision placing a ban on pollution from new outlets; and (3) a provision that federal authority can become operative only with the consent of the affected state. This provision is especially bad for it would render the federal authority inoperative in the very cases where it is needed most. Those states which are trying to control pollution will welcome assistance from the federal authority; those that are not interested in real control—and there are several states that are dominated by polluters—would be the very ones to refuse to give consent for the federal authority to intervene.

The pollution problem will never be fully solved until we have adequate federal authority to intervene when the state or the interested agency demonstrates either its inability or its unwillingness to do its own job.

COMMITTEE ON REVISION OF CONSTITUTION AND BY-LAWS

H. J. Deason

Pursuant to a resolution adopted at the Seventy-sixth Annual Meeting of the American Fisheries Society, the President appointed a Special Committee for the Revision of the Constitution and By-laws of the American Fisheries Society. The membership of the committee is H. J. Deason, chairman; James A. Rodd, and Seth Gordon.

At the outset, the revision of the constitution and by-laws for the purpose of bringing them up to date and to render them consistent with the various changes that have been adopted by the membership by resolution from time to time appeared to be a relatively simple task. Further study revealed, however, that many changes were desirable which the committee hesitated to propose or incorporate in the revised draft since the views of the membership had not been expressed fully, if at all, concerning them. Certain

other proposed changes in the organization that will materially affect the substance of the Constitution have been proposed informally to the committee, and one very important question has been referred to another special committee that is to report and make recommendations at this meeting. In view of these uncertainties and pending actions the committee concluded that any draft it might propose at this meeting would immediately be subject to material revision, and that the chances of the Society's reaching agreement at this meeting on a new constitution and by-laws that would adequately meet its needs and objectives are very slight.

The Special Committee on the Revision of the Constitution and By-Laws makes the following recommendations:

1. That the committee be continued in existence for another year and its membership increased from three to seven members, additional appointments to be made by the incoming President.

2. That the committee be instructed to prepare and circulate to the entire membership a revised draft of the constitution and by-laws at least 3 months prior to the date of the next annual meeting so that those in attendance at that meeting will be conversant with its provisions and be enabled to vote intelligently relative to its adoption.

3. That the topics that I shall now mention briefly, be referred by the President at this meeting to the Resolutions Committee or other appropriate committees for consideration and the presentation of recommendations for the action of the membership at the concluding session on Friday.

At a meeting of the Executive Committee of the Society held at San Antonio on February 5, 1947, the opinion was expressed by some of those present that the various divisional vice-presidencies were no longer serving a useful purpose and that these offices should be abolished. To refresh your memory I would point out that the divisional vice-presidencies were established for the purpose of bringing before the Society a report on current activities in their particular fields so that the Society could be informed on developments during the past year in aquatic biology, angling, commercial fisheries, ... If I may venture my own personal opinion, it is very strongly against abolishing the divisional vice-presidencies.

The present constitution and by-laws state that "The objects of the Society shall be to promote the cause of fish culture and its allied interests; to gather and diffuse information on all questions pertaining to fish culture, fish and fisheries; and to unite and encourage those interested in fish culture and fisheries problems." The American Fisheries Society, as many of you know, was originally founded as the American Fish Cultural Association. It continued under that name for the first few years of its existence, and later it was broadened into the American Fisheries Society. Up until about 20 years ago the American Fisheries Society seemed to be concerned primarily if not wholly with fish culture, fresh-water fisheries, and recreational fisheries, with little or no attention given to commercial fisheries. The trend during the last 10 or 15 years has varied: in some years we have had good representation of papers on the commercial fish-

eries and marine biology; in some years we have had none at all. The question before the committee on revision of the constitution is whether or not the purposes and objectives of the Society might be broadened to cover the whole field of interests and activities of the Society and thus interest more people in joining the organization.

When you approach some people who know nothing about the Society but have seen a copy of the Constitution, they assume at once that the American Fisheries Society is primarily concerned with fish culture and fresh-water fisheries. Now, the committee has arrived tentatively at a much broader definition of purposes and objectives of the Society. To many of the older members it might appear that this definition of purposes and objectives is too inclusive. I would like to read this draft and have your reactions to it:

> The purposes and objectives of the Society shall be: To promote the conservation, development, and optimum utilization of the fisheries and the fishery resources, both recreational and commercial; to promote and advance the development and application of all branches of fishery science, including aquatic biology, fish culture, limnology, oceanography, and fishery technology; to gather and disseminate information on fisheries, fishing, and all branches of fishery science and practice; to hold meetings for the exchange, presentation, demonstration, and discussion of information and experience, and to give encouragement to workers in techniques and practices relating to fisheries, fishing, and all branches of fishery science and practice.

There has been in the Society's Constitution for a great many years a provision for a category of member known as "corresponding member." The members of the Committee on Revision of the Constitution and By-Laws considered the matter and noted that no new corresponding members had been elected for many years; the question is suggested whether that category of membership serves any useful purpose. It seems to me that if corresponding memberships are to be retained they should not be conferred upon anyone who is resident in North America and could become a regular member of the Society. We have honorary memberships to take care of other classes of persons than active members. In view of the fact that the TRANSACTIONS bear no evidence, in recent years at least, of communications from corresponding members, I wonder if we could not just as well drop that category from the Constitution.

The suggestion has been made that a new category of member be established, namely, "complimentary member." A complimentary member would be defined as any person, not previously an active member, who has been elected by unanimous vote of those present at any regular meeting of the Society in recognition of outstanding services in relation to any of the objectives or activities of the Society, including meritorious assistance in connection with an annual meeting. There are probably many persons who in the normal course of events would not become active members of

the Society but who nevertheless contribute a great deal to the annual meeting. It is thought by the proposer of this suggestion that a complimentary membership might be offered to a small number of persons, not more than five in any one year. This type of membership would, as I have stated, give recognition to local officials, officers of other organizations, members of the press, or other persons who have performed services or given assistance, other than financial, to the Society. Such memberships, limited as I have said to five individuals each year, would be good for only one year. The complimentary member would be given a free copy of the TRANSACTIONS of the meeting at which he was elected.

Some items have already been resolved by the reports of previous special committees, so there is no need to mention them. The remainder will now be referred to the Resolutions Committee.

COMMITTEE TO CONSIDER INCREASE OF DUES

A. D. ALDRICH

The committee to consider the need for raising the dues of the Society has not had adequate time to give due consideration to all the factors involved. It seemed to be the opinion of such members as we were able to consult in the limited time at our disposal that if an increase in the dues would hasten the publication of the TRANSACTIONS, it would be unanimously approved. However we find, as Dr. Hile explained, it is not a matter of funds. Furthermore the Secretary-Treasurer reports his fiscal balance as favorable, and assures us that there are enough funds available to print the TRANSACTIONS at the present rate of issue. Therefore the Committee does not recommend any increase in dues at this time.

COMMITTEE ON FORMATION OF WESTERN DIVISION

T. H. LANGLOIS

Interest in the formation of a western division of the American Fisheries Society seems to have originated largely among United States members of the western region. A canvass of the Canadian members of the Society reveals an almost unanimous opinion against the formation of a separate western division.

I noted from the report submitted by our Secretary this morning that there are approximately 125 United States members from California, Washington, Oregon, and Montana. A very considerable proportion of our total membership seems to come from those few western states.

The principal argument in favor of a western division was that many of the members who do not now come east to participate in our annual meetings would be able to get together each year, and that a further increase in membership might result.

There are many arguments for and a few against the formation of a western division. The administrative problems involved would be considerable. Various methods have been proposed for solving those problems. It was suggested for instance that if we were to have a western division it would be desirable to have not only a President but at least an administrative vice-president in each of these two divisions, and that some arrangement be made to alternate the office of President—to have one first from the east side and then one from the west. The Secretary-Treasurer of course has been from the east; it might be necessary to have a second Secretary-Treasurer to take care of the western division business.

The principal advantage to the Society as I see it is that there might be a material increase in the number of members from that area. If added membership would increase the number of copies of TRANSACTIONS published it is possible we could get a better quality of volume for no great increase in cost. However, the problems of administering a separate western division as a functional part of a national society such as this should be considered. I do not believe they are insurmountable.

I suggest that the matter be given further consideration, and that the Resolutions Committee be given the task of ascertaining the sentiment of the group by preparing and submitting a resolution favoring the establishment of a western division. Then the members now present will have an opportunity to approve or disapprove the proposal.

[By vote of the Society, the question of forming a western division was referred to the Resolutions Committee.]

COMMITTEE TO CONSIDER ESTABLISHMENT OF A QUARTERLY JOURNAL

REEVE M. BAILEY [1]

Historically, the publication of this Society was established as a medium for recording the proceedings of the annual meetings. Originally known as the PROCEEDINGS OF THE AMERICAN FISH CULTURISTS' ASSOCIATION, it was first titled TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY in the volume for 1885. The reports were published as annual volumes from 1872 until the present, except for the period 1914 to 1920. By authorization of the Council of the Society, Volume 44 (1914) appeared as a quarterly without change of title. An explanation for the change is contained in the report of the recording secretary (Vol. 45, p. 81) as follows:

> The chief arguments in favor of the more frequent publication were, first, that the Transactions would reach the members more frequently and thus have a greater influence in keeping awake their interest in

[1] In the absence of Dr. Bailey, the report was presented by Mr. John Gottschalk, member of the Committee.

the work of the Society, and second, that scientific papers could be issued without waiting for other matters, while the Proceedings of the Annual Meeting, the list of members, etc., would still appear about as early as formerly. In arranging material for publication, preference was given, as far as possible, to those papers read and discussed at the annual meeting.

The Secretary believes that the change is fully justified, as he has received many letters and other expressions of approval from the members and has yet to hear of a single objection.

Publication of a single annual volume was resumed with Volume 50. In the secretary's report (Vol. 51, p. 14) the reasons were chronicled as follows:

> Preliminary to this undertaking much careful consideration was given to the desirability of resuming the practice in effect prior to 1914 of publishing the Transactions in one volume instead of quarterly issues. One volume seemed desirable both upon the grounds of economy and convenience. Investigation showed that it could be issued cheaper than the quarterlies, notwithstanding its inadmissibility at the low second class mail rate. Also it appeared that there was dissatisfaction with the quarterlies because of the greater chance of their becoming misplaced and causing incomplete sets. So with the approval of officers of the Society one volume was decided upon. This course has met with hearty endorsement.

The present dilemma on publication of the TRANSACTIONS is a matter of record. For reasons beyond the control of the present Editorial Board, Volumes 74, 75, and 76, all of which should now be in print, are in various stages of printing or editing.

It has now been proposed that the Society again consider the possibility of publishing a quarterly journal. It is the opinion of the committee that until the TRANSACTIONS can be brought up to date, any change in the present plan of publication would be premature. The temporary delay thus imposed provides adequate time to study the publication problem thoroughly.

In its simplest form, a quarterly publication might be nothing more than the transactions of the annual meeting issued in four parts—neither adding to nor deleting from the content of an annual volume. Such a plan seems to have little in its favor. In comparison with the issuance of an annual volume, such a quarterly would be more expensive, would require more editorial time, and would add little or not at all to speed of publication. We have heard no support for this plan from the members of the Society, and the committee votes unanimously for its rejection.

There remain three alternative plans for publication which are hereinafter designated by letter:

A. Publish the TRANSACTIONS as a single annual volume, as in recent years.

B. Discontinue publication of the TRANSACTIONS, and replace the series by a quarterly journal which would include, in addition to papers, the business of the Society and symposia.

C. Continue publication of the TRANSACTIONS as an annual volume devoted to the presentation of the business of the Society and symposia, *and* establish a new quarterly journal for the publication of formal papers.

It is anticipated that a new journal (Plan B or Plan C), unencumbered by precedent, could be designed to meet the vital need for an active, high-quality fishery journal. It should be a scientific quarterly which would be thoroughly modern in format and scope, with additional features such as a notes section, book reviews, current literature, and news items. These added departments would do much to increase the utility, interest, and attractiveness of the publication. It is beyond the province of this committee to outline format and objectives for such a journal, but it is clear that an editorial board should receive and publish papers as promptly as possible irrespective of their presentation at the annual meetings.

In order to appraise the merits of the three plans they are contrasted two at a time.

Plan A versus Plan B.—A change from Plan A to Plan B has the following points in its favor:

(1) More rapid publication of papers would be facilitated.

(2) Presentation of a paper at the annual meeting would not be a necessary prerequisite to publication.

(3) Manuscripts could be submitted for publication when completed instead of only at the time of the annual meetings.

(4) New and up-to-date information could be provided through the medium of feature sections.

(5) Despite the great importance of the present TRANSACTIONS there exists a real need for a fishery periodical which would aid in centralizing the now widely scattered outlets for publication of studies in fishery biology, and which should lead to a substantial increase of both active and library membership.

On the other hand, this change would have the following disadvantages:

(6) The work of the Editorial Board would be appreciably increased.

(7) The cost of publishing, binding, and mailing four issues each year would be considerably greater than for a single volume.

(8) Since the title TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY implies that the publication is devoted to a record of the meetings of the Society, transformation of the TRANSACTIONS into a quarterly journal incorporating desirable features of progressive periodicals would constitute a contradiction of the title. A change in title would be in order, and thus the TRANSACTIONS would come to an end after nearly 80 years of publication.

Plan A versus Plan C.—Plan C would realize all of the advantages which B has over A (see 1 to 5 above) and in addition:

(9) The editorial handling of business sessions and scientific papers could be segregated.

(10) The continuity of the TRANSACTIONS as a serial publication would be maintained.

To make the change from Plan A to Plan C would create two problems:

(11) The editorial work would be appreciably increased, and would be complicated by the necessity of meeting five deadlines each year. Also, provision would have to be made for editing and publishing two serial publications.

(12) The cost of publishing, binding, and mailing five publications yearly would be considerably greater than for a single volume.

Plan B versus Plan C.—These plans both call for sponsorship by the Society of a new fishery journal. They differ only in the place of publication of the proceedings and symposia of the Society.

Some will favor Plan B over Plan C because:

(13) It involves publication by the Society of only one serial.

(14) The cost of publishing, binding, and mailing four issues each year would be slightly less than for five issues. (For this comparison it is fair to assume an equal amount of copy.)

Others will favor Plan C over Plan B because:

(15) It does not sound the death knell of the TRANSACTIONS.

(16) The editorial handling of business sessions and scientific papers could be segregated.

(17) It would eliminate the necessity of devoting one issue of the journal each year to publication of the business sessions, appendices, and index.

After careful consideration of these proposals, it is the unanimous belief of the committee that the Society should adopt a quarterly publication, Plan B or Plan C. A majority of the committee favors retention of the TRANSACTIONS for publication of Society business and symposia, and the creation of a new quarterly journal (Plan C). One member (Gottschalk) prefers that Society business and symposia be incorporated into a quarterly journal (Plan B), but he willingly subscribes to Plan C. If either plan is adopted by the Society an increase in revenue will be needed to defray additional costs of publication.

Contingent on Society support of the recommendations of this report, the committee suggests that another special committee be appointed to formulate policy and format for the future publications of the Society.

Summary.—The committee (1) urges that no change in present publication policy be initiated until the Editorial Board has had sufficient time to get the TRANSACTIONS up to date; (2) strongly recommends that the Society not dismember the present annual TRANSACTIONS into four quarterly issues; (3) unanimously approves publication by the Society of a modernized quarterly fishery journal; and (4) recommends by a four to one majority a plan to continue publication of the TRANSACTIONS as an annual business report of the Society that should include also symposia and panel discussions presented at the annual meeting.

Furthermore, the committee suggests that a special committee of indefinite tenure be appointed to continue plans for the proposed changes.

MR. HIGGINS: I should like to speak in favor of the proposal presented by the Committee. This Society, I believe, is the proper agency to sponsor such an effort. The circulation of a quarterly journal would be twice, perhaps three times as great as that of the present TRANSACTIONS; you would reach a much larger audience. You would receive subscriptions from non-members, and the mere publication of such a journal would stimulate membership in the organization. I strongly favor this Society's going to some trouble and making some sacrifice if necessary to render such a service to our science.

DR. LANGLOIS: I too am in accord with the report submitted, but in view of the fact that it may be 1950 before we catch up with publication of our TRANSACTIONS, I would urge that no action be taken to start such a journal until the present lag in publication is overcome.

DR. GOTTSCHALK: My own feeling is that it might be well for us to think about the problem a little more and perhaps bring it to a vote tomorrow.

DR. VAN OOSTEN: Why not adopt this report—make a special motion to accept the recommendations of the Committee and have the Committee extended until next year? We will then have a year to think about it, instead of just a few hours.

DR. LANGLOIS: It seems to me it might be well to defer any definite commitment on point 3—"unanimously approve publication by the Society of a modernized quarterly fishery journal." I believe we are not quite ready for that. I would be inclined to approve the action of the committee without expressing entire approval of all the points listed in their summary.

DR. VAN OOSTEN: I move that we accept the report of the committee.

[The motion was seconded by Dr. Langlois, and adopted.]

MR. GOTTSCHALK: I move that the special committee recommended by this committee be appointed by the president, to present a report in complete detail at the next annual meeting.

[The motion was seconded by Dr. Langlois, and adopted.]

REPORTS OF SESSIONAL COMMITTEES

COMMITTEE ON TIME AND PLACE

LESTER BAGLEY

The Committee on Time and Place met with the corresponding committee of the International Association of Game, Fish, and Conservation Commissioners. It was agreed that, following the custom of rotating meetings among various geographical regions of the continent, the next annual meeting should be held in the east. Therefore the invitation of Atlantic City, N. J., was accepted for the 1948 annual meeting. The question of which society should convene its sessions first was held over for further discussion and decision at a later date. Sentiment was also expressed that the 1949 meetings might properly be held in Canada, with preference for one of the prairie provinces.

AUDITING COMMITTEE

JAMES N. GOWANLOCH

The Auditing Committee has gone over the accounts of the American Fisheries Society and has found everything correct and in good order.

RESOLUTIONS COMMITTEE

PAUL R. NEEDHAM

1. Establishment of a Western Division of the Society

WHEREAS, A substantial segment of the membership of the American Fisheries Society is resident in the western part of the United States and the western provinces of Canada and because of the long distances to most of the places selected for annual meetings such western members have little opportunity to participate directly in the work and programs of the Society; and

WHEREAS, An informal canvass of the membership of the Society has indicated that the establishment of a Western Division of the American Fisheries Society with authority to hold annual meetings would stimulate interest in the work of the Society and assist in furthering its purpose and objectives; now therefore

BE IT RESOLVED, That the American Fisheries Society at its Seventy-seventh Annual Meeting at Denver, Colorado, September 12, 1947, directs the Special Committee on the Revision of the Constitution and By-Laws of the Society to make appropriate provision in the new draft of the constitution for the establishment of a Western Division of the Society, which shall elect its own officers consisting of a President, Vice-President

and a Secretary, and which shall be authorized to adopt suitable rules of procedure for the conduct of its business and meetings, provided such rules of procedure are not inconsistent with the Constitution and By-Laws of the Society as a whole; and

BE IT FURTHER RESOLVED, That pending the consideration and adoption of a revised constitution and by-laws for the Society the incoming President is authorized to appoint a provisional chairman of an interim Western Division and an organization committee of five members from the western states of the United States, and the western provinces of Canada and Mexico; such provisional chairman and organization committee to serve for one year and to make plans for the formal establishment of the Western Division at such time as a revised constitution of the Society is adopted authorizing such establishment; and that such plans for the establishment of the Western Division may include the convocation of members of the Society in western North America at meetings to be held at the discretion of and at such places as may be determined by the provisional chairman with the advice of the organization committee.

2. Continuance of the Special Committee on the Revision of the Constitution and By-Laws

WHEREAS, A Special Committee for the Revision of the Constitution and By-Laws of the American Fisheries Society was established by a resolution adopted at the Seventy-sixth Annual Meeting; and

WHEREAS, The Committee has been unable to complete its work because of the need for further instructions from the membership which have been and are being provided through actions at the Seventy-seventh Annual Meeting; now therefore

BE IT RESOLVED, That the Special Committee on the Revision of the Constitution and By-Laws is hereby continued for an additional year, and its membership increased from three to seven, new members to be appointed by the incoming President; and

BE IT FURTHER RESOLVED, That a revised draft of the constitution and by-laws is to be completed and mailed on or before June 1, 1948, to all members of the Society in good standing and that consideration of the proposed new constitution and by-laws be made an order of business at the Seventy-eighth Annual Meeting.

3. Public Lands Question

WHEREAS, Representatives of the western livestock industry have supported programs which if enacted into federal legislation would:

(1) Provide a means for passing title of public domain grazing lands to livestock growers,

(2) Convert the grazing privilege in national forests to a property right,

(3) Confer administrative authority on national forest livestock advisory boards; and

WHEREAS, The current hearings in the western states by the Subcommittee on Public Lands of the House of Representatives are being conducted in a manner to favor the viewpoint of the livestock users of the national forests and are not in the public interest; and

WHEREAS, These public lands contain much fine fishing water and afford high values in water, recreation, game, etc.—values which should be protected and administered by public agencies in the public interest; now therefore

BE IT RESOLVED, By the American Fisheries Society at its Seventy-seventh Annual Meeting at Denver, Colorado, September 12, 1947, that the Society go on record as opposing:

(1) The transfer of public grazing lands to private ownership.

(2) The acquisition by any special group of grazing rights or administrative control on western public lands.

(3) The biased manner in which the public land hearings are being conducted; and

BE IT FURTHER RESOLVED, That the Secretary of the Society is hereby directed to send certified copies of this resolution to the President of the United States Senate, the Speaker of the House of Representatives, the Secretary of Agriculture, and the Secretary of the Interior.

4. Conservation in Relation to the Proposed Japanese Peace Treaty

WHEREAS, The Japanese government and its people for decades have exploited wantonly the biological resources of the lands and waters of the Japanese islands; of adjacent foreign territories under lease agreement, expropriation, and seizure; and of areas of the high seas throughout the Pacific Ocean and its dependent seas; and

WHEREAS, The diminution of the resources in the Japanese islands through over-exploitation and unwise utilization led to the expansion of Japanese exploitation of the fishery resources adjacent to the coast of North America, in total disregard of the fact that such resources in many instances were being maintained and conserved by the imposition of conservation regulations and management measures either unilaterally or jointly by the United States of America and the Dominion of Canada, which regulations prevented over-exploitation of the resources by nationals and vessels of the regulating countries; and

WHEREAS, the Japanese government has, in the past, proven itself untrustworthy in carrying out obligations under international conservation agreements to which it has become a party and which it has ratified; and although it has been a signatory of at least one international convention for conservation of natural resources, it later refused to ratify with the result that wanton exploitation of depleted resources was carried on without regard to international regulations; and

WHEREAS, Consideration is now being given by the United States government and other allied powers to the drafting of a Japanese peace treaty; now therefore

BE IT RESOLVED, That the American Fisheries Society, at its Seventy-seventh Annual Meeting held at Denver, Colorado, September 12, 1947, urges upon the Government of the United States of America and the other governments concerned with the drafting and negotiation of a Japanese peace treaty the absolute and material necessity of including within the articles of said treaty such binding obligations to be assumed by the Japanese government as will ensure for all time that the Japanese peoples must accede to and abide by all existing and future international agreements for the conservation and management of natural biological resources, and that, in respect of the biological resources of the Japanese territories and adjacent waters, conservation and management practices will be instituted and maintained so as to safeguard the resources from depletion and over-exploitation; and

BE IT FURTHER RESOLVED, That the Secretary of the American Fisheries Society is hereby directed to transmit certified copies of this resolution to the President of the United States of America, the Secretary of State of the United States of America, the Prime Minister of Canada, and the Secretary of State for External Affairs of Canada.

5. Expert Analyses of Cost-Benefit Ratios Set Up by Federal Agencies

WHEREAS, The Corps of Engineers of the United States Army and the Bureau of Reclamation are framing long-range multiple-purpose water development programs of basin-wide national scope; and

WHEREAS, Many of these projects are certain to have serious effects on wildlife generally but especially on the fishery resources of the nation; and

WHEREAS, The calculated cost of each project is compared to the benefits to be gained from each and set up as a cost-benefit ratio in each; and

WHEREAS, Many of the cost-benefit ratios prepared for release to the public appear to have been greatly exaggerated in terms of benefits to accrue from flood control, power, irrigation and navigation; now therefore

BE IT RESOLVED, That the American Fisheries Society at its Seventy-seventh Annual Meeting held in Denver, Colorado, September 12, 1947, unanimously urge that expert, unbiased analyses be made of all cost-benefit ratios presented by the constructing agencies; and

BE IT FURTHER RESOLVED, That experts in the fields concerned be obtained to make such analyses and that they be paid from funds not appropriated to the constructing agencies; and

BE IT FURTHER RESOLVED, That the Secretary of the Society is hereby directed to transmit a certified copy of this resolution to the Secretary of War and to the Secretary of the Interior.

6. Proposed International Convention for the Northwestern Atlantic Fisheries

WHEREAS, During recent years there have become evident unmistakable signs of decreases in the abundance and productiveness of the Northwestern Atlantic fisheries which are not attributable to any natural population

fluctuations but which are definitely related to increasing exploitation of the resources, and thus once important species have declined in abundance so that they support an insignificant annual yield, and other species are declining in annual yield so that it is necessary for vessels to fish harder, longer, and farther from their home ports in order to make profitable catches; and

WHEREAS, The principal fishery species of the Northwestern Atlantic Ocean are distributed and move without regard to international boundaries, and in fact occur primarily in waters beyond the limits of territorial jurisdiction, but by reason of adjacency such resources are the joint concern primarily of the United States of America, Canada, Newfoundland and France; and

WHEREAS, Certain fishing banks in the Northwestern Atlantic Ocean also have been exploited for varying periods of time and with varying intensity by nationals and vessels of European countries, and their exploitation is increasing due to the inability of the Eastern Atlantic Ocean, the North Sea, and the Mediterranean Sea to support fishery enterprises and yields commensurate with the European demand for fishery products both for local consumption and export in the interest of reestablishing international trade; and

WHEREAS, Certain European nations concluded at London in April 1946, an international convention for the prevention of overfishing which provides for the joint regulation of the fisheries of the high seas of the eastern North Atlantic Ocean, the North Sea and certain other connecting and adjacent waters, thus leaving the Northwestern Atlantic Ocean as an attractive, productive fishing area open to wanton exploitation; now therefore

BE IT RESOLVED, That the American Fisheries Society, at its Seventy-seventh Annual Meeting, held at Denver, Colorado, September 12, 1947, add its support to those segments of the fishing industry and other public and private groups who believe that the conclusion of an international convention for the conservation of the fisheries of the Northwestern Atlantic is both timely and necessary, and urge that the Government of the United States of America and the Government of Canada assume an aggressive and forceful role in the immediate drafting and early conclusion of such a convention by all interested governments, to the end that there shall be established continuing joint and cooperative studies and investigations of the fisheries of the area which will provide a continuing fund of authoritative facts and recommendations that will provide a sound basis for regulating, conserving, and safeguarding for the future the fisheries of the area; and to the further objective of ensuring that no nation nor person nor vessel exploits those fisheries on any basis that will constitute undue advantage and jeopardy of the resources; and

BE IT FURTHER RESOLVED, That the Secretary of the American Fisheries Society is hereby directed to transmit certified copies of this resolution to the President of the United States, the Prime Minister of Canada, the Secre-

tary of State of the United States, the Secretary of State for External Affairs of Canada, the Secretary of the Interior of the United States, and the Minister of Fisheries of Canada.

7. Great Lakes Treaty

WHEREAS, The Government of the United States of America and the Government of Canada concluded on April 2, 1946, an international convention for the protection, development, and conservation of the Great Lakes fisheries; and

WHEREAS, The American Fisheries Society at the Seventy-sixth, Seventy-second, and other Annual Meetings adopted unanimously resolutions urging the conclusion and adoption of an international treaty as the most satisfactory solution to the problem of providing for unified and concerted action in conserving and safeguarding the fisheries of the Great Lakes from further depletion; now therefore

BE IT RESOLVED, That the American Fisheries Society, at its Seventy-seventh Annual Meeting held at Denver, Colorado, September 12, 1947, reaffirms its previous resolutions and recommendations concerning international regulation of the fisheries of the Great Lakes and earnestly recommends that the governments of the United States of America and of Canada ratify promptly the international convention of April 2, 1946, for the protection, development and conservation of the Great Lakes fisheries, and that the Congress of the United States and the Parliament of Canada enact appropriate implementing legislation; and

BE IT FURTHER RESOLVED, That the Secretary of the American Fisheries Society is hereby directed to transmit certified copies of this resolution to the President of the United States, the Prime Minister of Canada, and to appropriate officers of the United States Congress and the Parliament of Canada.

8. Proposed International Fisheries Convention between the United States of America and the United Mexican States

WHEREAS, The fishery resources of the Gulf of Mexico and of certain areas of the Pacific Ocean adjacent to the coast of North America are of joint interest and concern to the United States of America and the United Mexican States; and

WHEREAS, There is need for further knowledge of the abundance, distribution, ecology, and other biological features of the species of fisheries of common interest and concern; and

WHEREAS, Such biological information and the recommendations therefrom are an indispensable basis for the conservation and management of the fishery resources of the area, and the establishment of regulations to achieve that objective should be undertaken immediately upon the established need for such regulation without awaiting catastrophies in the fisheries which may be so serious that recovery of the resource is impossible; and

WHEREAS, Certain minor disputes and misunderstandings of an international nature between the governments of the United States of America and the United Mexican States arise from time to time which point to the need for mutual understandings concerning the fisheries of common concern; and

WHEREAS, Many interests, enterprises, and individuals in both countries have urged upon their respective governments the desirability of concluding an international treaty to achieve the foregoing purposes and objectives, and drafts of such an instrument already have received preliminary consideration; now therefore

BE IT RESOLVED, That the American Fisheries Society, at its Seventy-seventh Annual Meeting, held in Denver, Colorado, September 12, 1947, urgently recommends the conclusion of an international fisheries convention between the United States of America and the United Mexican States for the purpose of establishing a system of managing the fisheries of common concern through information and recommendations resulting from continuing fishery research conducted jointly and cooperatively by the contracting governments and by other qualified organizations and institutions within both countries; and

BE IT FURTHER RESOLVED, That the Secretary of the American Fisheries Society is hereby directed to transmit a certified copy of this resolution to the President of the United States of America, the President of the United Mexican States, the Secretary of State of the United States of America, the Minister of Foreign Relations of Mexico, the Secretary of the Interior of the United States, and the Secretary of the Marine of Mexico.

9. The Honorable H. Francis G. Bridges, In Memoriam

WHEREAS, Through the untimely death of the Honorable H. Francis G. Bridges, Member of the Parliament of Canada, Minister of Fisheries of Canada, and Honorary Member of the American Fisheries Society, fisheries and fishery science have lost an able administrator, staunch and inspiring advocate, and worthy friend; now therefore

BE IT RESOLVED, That the American Fisheries Society, at its Seventy-seventh Annual Meeting, held at Denver, Colorado, September 12, 1947, unanimously expresses its sincere sorrow at the death of the Honorable Mr. Bridges, and extends an expression of its sympathy and condolence to the people of Canada in their loss; and

BE IT FURTHER RESOLVED, That the Secretary of the Society is hereby directed to transmit a certified copy of this resolution to the Speaker of the House of commons of the Parliament of Canada and to the family of the late Mr. Bridges.

10. Appreciation to Local Committee

WHEREAS, The Colorado Fish and Game Department, through its Director, Mr. Cleland Feast and his staff members serving as hosts to the

Seventy-seventh Annual Meeting of the American Fisheries Society, went to considerable trouble, effort, and expense to make the meeting a success; and

WHEREAS, The many courtesies extended and aid given contributed in no small measure to individual pleasure, comfort, and convenience of the members in attendance; now therefore

BE IT RESOLVED, that the American Fisheries Society extend its sincere thanks to Mr. Feast and the members of his staff; and

BE IT FURTHER RESOLVED, That the Secretary of the Society is hereby directed to transmit a copy of this resolution to the Director of the Colorado Fish and Game Department.

COMMITTEE ON NOMINATIONS

C. M. MOTTLEY

In drawing up this list of names the Committee on Nominations has given the usual consideration to representation of the country at large.

OFFICERS

President .....H. H. MacKay, Ontario
First Vice-President .....Seth Gordon, Pennsylvania
Second Vice-President .....M. C. James, District of Columbia
Librarian .....Kenneth E. Cobb, Connecticut

VICE-PRESIDENTS OF DIVISIONS

Fish Culture .....O. R. Kingsbury, New York
Commercial Fishing .....A. W. Anderson, District of Columbia
Aquatic Biology and Physics .....Paul R. Needham, Oregon
Angling .....James C. Simpson, Idaho
Protection and Legislation .....R. W. Eschmeyer, Tennessee

COMMITTEE ON INTERNATIONAL RELATIONS

James N. Gowanloch, Louisiana, *Chairman*
George W. Davis, Vermont
H. J. Deason, District of Columbia
James A. Rodd, Ontario
Alan C. Taft, California
Fred Thompson, New Mexico
John Van Oosten, Michigan

COMMITTEE ON STATE AND NATIONAL RELATIONS

W. D. Heydecker, New York, *Chairman*
A. D. Aldrich, Oklahoma

Albert M. Day, District of Columbia
John Gottschalk, Montana
C. R. Gutermuth, District of Columbia

Dr. Mottley: I have the adoption of this list.

[The motion was seconded by Mr. Aldrich and adopted, and the Secretary was instructed to cast a ballot for the names set forth on the list recommended by the Committee on Nominations.]

CONCLUDING BUSINESS

THE RETIRING PRESIDENT: There was the question of the need for a list of about 10 men which would be available to the Director, U. S. Fish and Wildlife Service, in connection with expert testimony in Washington before congressional committees dealing with proposed legislation affecting matters which are the concern of this organization. What is the pleasure of the meeting in that respect?

DR. MOTTLEY: I move that the First and Second Vice-President act as a committee to draw up a list of names to assist in the matter of aiding and expediting federal legislation.

[The motion was seconded by Dr. Schneberger and adopted.]

THE RETIRING PRESIDENT: Another question concerns the sequence of the annual meetings of the American Fisheries Society and the International Association of Game, Fish, and Conservation Commissioners. These has been considerable correspondence and discussion about the order in which the two meetings should be held, and I believe it would be well to consider the matter now so as to relieve the Executive Committee of responsibility for the decision. There is much to be said on each side of the question, but I merely bring it up for purposes of discussion. Do you want the International to meet first each year with the American Fisheries Society coming second, or do you want the meetings to be rotated as previously. I believe we should have some expression of opinion.

DR. DEASON: It has been a long-standing practice to rotate the two meetings. There is no doubt that the organization which meets first gets most of the publicity; interest seems to dwindle toward the end of the week; consequently our meeting should be alternately first. I would like to see the American Fisheries Society and the International Association return to the former procedure of alternating the order of meetings.

DR. HUNTER: The new Constitution and By-Laws adopted this year by the International Association provide that the meetings shall be held the week beginning the second Monday in September and that the International Association shall meet in the first part of the week. Provision is also made, however, for Executive Committees of both societies to confer on the matter.

MR. GORDON: That is right; the two committees working together have power to alternate the meetings if they see fit.

DR. HUNTER: If this Society wishes to express itself as desirous of meeting in the early part of the week next year, its Executive Committee can be instructed to confer with the Executive Committee of the International and make the necessary arrangements.

DR. HILE: I move that the American Fisheries Society go on record as favoring resumption of the long-established system of alternating meetings with the International Association.

[The motion was seconded by Mr. Chute and adopted.]

THE RETIRING PRESIDENT: I think that concludes this part of the business session. I wish to thank all of you who have worked with me in the past year, especially those who have been closely connected with the Society and its work. I want to assure you it has been a pleasure to work with you.

We owe a great debt of thanks to the Colorado people for their courtesy and hospitality.

I now have much pleasure in turning the meeting over to the newly elected President, Dr. MacKay.

THE PRESIDENT-ELECT: Mr. Hogan, and fellow members of the American Fisheries Society, I thank you most sincerely for the honor you have conferred upon me in electing me to the presidency of the Society. I shall do my utmost to maintain the high standards of my predecessors in office, and shall bend every effort to furthering the interests of the Society wherever those interests may lie.

The past is best preserved in that which grows. We face toward tomorrow, and with the able corps of officers selected by your Nominating Committee, and with the help of an active membership, we should be able to advance the cause of conservation, a cause in which we have all enlisted for service.

In order to expedite next year's program I have taken it upon myself to name a Program Committee so that they can begin early to arrange the program for next year. The following committee has been appointed:

Charles M. Mottley, District of Columbia, *Chairman*
W. A. Clemens, British Columbia
John S. Dendy, Alabama
A. S. Hazzard, Michigan
A. G. Huntsman, Ontario
Paul R. Needham, Oregon
Douglas Omand, Ontario

I thought it would be wise to have the members of this committee scattered throughout the different areas so that we would have an excellent representation of at least the two countries.

The present membership of the Editorial Board has been continued without change for another year.

In the report of a special committee to consider the possibility of publication of a quarterly journal by the American Fisheries Society it was suggested that a special committee of indefinite tenure should be appointed to continue plans for the proposed changes. I think it is desirable that the members of the original committee should act as a special committee of indefinite tenure. This committee has the following members:

Reeve M. Bailey, Michigan, *Chairman*
John S. Gottschalk, Montana
Ralph Hile, Michigan
Justin W. Leonard, Michigan
E. L. Wickliff, Ohio

The committee to revise the constitution and by-laws has requested that its membership be increased from three to seven members. I name the following additional members:

Frederick J. Foster, Washington
W. A. Clemens, British Columbia
George W. Davis, Vermont
R. W. Eschmeyer, Tennessee

I think also that in advance of next year's meeting a Resolutions Committee should be appointed, and the following committee has been named:

H. J. Deason, District of Columbia, *Chairman*
James N. Gowanloch, Louisiana
J. A. Rodd, Ontario
Alan Taft, California
Fred A. Westerman, Michigan

The resolution which was adopted by the Society, authorizing the formation of a Western Division, requested that the incoming President name a provisional Western Division Committee consisting of a Chairman and five members to serve for one year only, that is until the amendments to and revision of the constitution and by-laws of the Society should be authorized. I therefore name the following committee:

Fred Thompson, New Mexico, *Chairman*
John L. Hart, British Columbia
Marion Madsen, Utah
Paul R. Needham, Oregon
William Reavley, Montana
Alan Taft, California

I do not know of any new business that is to come before the meeting. I should like to ask now for a rising vote of thanks to Mr. Hogan for his excellent leadership.

[The members expressed their appreciation by a rising vote of thanks.]

At 4:10 p.m. September 12, 1947, the Seventy-seventh Annual Meeting of the American Fisheries Society was adjourned.

Appendices

INSTRUCTIONS FOR PREPARING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1949)

Please check each item below before the final typing of your manuscript and help your Society reduce the costs of publication, save your Editorial Board (which works gratis) much needless work, time, and expense, and avoid delay in the publication of the *Transactions*.

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals (Government Printing Office Style Maanual; University of Chicago Style Manual). Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. **Manuscript must be typewritten double-spaced,** including titles, headings, legends for tables and illustrations, and literature citations. Use one side only of sheet. Do not fold manuscript. Write manuscript only in simple upper and lower case. *Do not use all capital letters for any purpose and underscore only where italics are intended.*

2. **Carbon copies will not be accepted.** Do not use thin, transparent paper. Heavy bond paper is preferred.

3. **Margins** at top, bottom, and both sides must be no less than 1¼ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. **Pages** must be numbered in consecutive order, including the literature cited, tables, charts, and photographs. Tables and legends of charts and illustrations must be inserted near their place of reference in the text.

5. **Illustrations.** Make separate pages of tables with headings (not of leader work), of legends of diagrams, charts, and illustrations, and limit the number to those absolutely necessary to clarify or supplement text. *Tables and cuts cost money!* Only sharp, glossy photos can be used. All drawings, charts, and diagrams should be prepared in waterproof India ink on Bristol Board, other perfectly smooth white paper or cardboard, or tracing cloth. Gaph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the shading lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed 4¼ by 6½ inches (inclusive of legends) when reduced. All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend. The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, charts, and tables, and designate all of these, except tables, as figures, numbering them in consecutive order with Arabic, not Roman, numerals.

6. **Footnotes** in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1.

7. **The title** of the manuscript, together with the author's name (write out in full either one or both of the Christian names and do not use "by"), position or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

REPORT ON THE DISEASES OF BROOK TROUT

John Edward Doe

Department of Conservation, Lansing, Michigan

8. **Underscore** (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius. Do not underscore any words unless italics are intended.*

9. Inspect papers in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in parentheses, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below to be placed at end of paper:

Literature Cited

Doe, John C., J. W. Brown, and H. W. Green

1939. Report on the diseases of brook trout. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 450–461.

Note that the year of publication precedes the title and the year of the meeting is stated in the reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and very inaccurate. Help us correct this situation.

11. **Tables.** Every table should have a heading and must be typewritten on a separate page. Insert tables among the text pages near the points where they are discussed. In preparing tables please be certain that they are not too large to appear on a single printed page. Number tables consecutively with Arabic, not Roman, numerals (1, 2, 3, etc.). Abbreviate the word "number" (No.) when referring to a special number—not when referring to quantity or things. Spell all other words in

Item	Number of fish	Percentage of total	Average length millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.25

tables, including such words as "millimeters," "ounces," and "average" (except months *with date,* in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

12. **Capitals.** Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to a particular State, Government, and to organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Hoover Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. **Abbreviations.**

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures, F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

Number, if preceding figures—No. 125; otherwise spell out.

United States, if preceding name of a department or a bureau of a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana.*

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5-September 2.

Measures and weight, except p.p.m., 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage, 12 percent, a percentage of 25.5.

14. **Numerals.** Spell out all *isolated* numbers less than 10, but use figures in a group of enumerations when any one number of that group is 10 or greater. Do not spell out numbers of two or more digits (except round numbers of approximations: estimated at five hundred; a thousand fish), and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were nine trout. There were 9 trout, 120 bass, and 50 pike.

Use figures for all enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth inch). For example: $3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; the 1st of January, 1938; the 20th day of March; 1937-38; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch trout; 120 6-inch trout.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

Spell out such indefinite expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout.

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. **Use of hyphen.** Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentence: "This species is adapted to *"cold water."* "Trout are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

Write "largemouth" and "smallmouth" as one word when referring to black bass.

III SUBJECT MATTER

16. **Condense your paper** to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. **Papers which are too poorly written will be rejected.**

17. **Be definite in references to species.** The scientific name, and wherever needed the *complete* common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "Bass," "trout," and "pickerel" apply to any one of several species. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth black bass," "brook trout," "rainbow trout," etc.

18. **Things to avoid.** Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "show," "found," "gave," and "present" are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives*. Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: *"This* was true in every *case." "The mortality* was *high* in every *pond."*

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. **Abstract of paper.** Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

Prepared by the Editorial Board
February 1937 (revised 1949)

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